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FOR ENVIRONMENTAL MANAGEMENT

AN EVALUATION OF STRATEGIES FOR PROMOTING EFFECTIVE RADON MITIGATION

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FOREWORD

Research reported here and elsewhere has increasingly pointed to a major problem faced by the U.S. Environmental Protection Agency and other environmental regulatory agencies, namely, that there is a widespread difference between the level of risks perceived by the public and those determined by professional risk analysts. Some risks are perceived by the public as being much worse than analysts believe they are; other risks are largely ignored by the public even though analysts believe them to be of major importance. Radon is an example of the latter type of risk. Risk analyses conducted by the National Academy of Sciences and EPA have concluded that the risks from radon are very high, and it appears likely that they are as high or higher than for any other pollutant not yet substantially controlled by EPA. Yet the research reported here strongly argues that the public is doing comparatively little in terms of actually remediating their homes to reduce the risks they are exposed to.

This study reports on the relative effectiveness of a broad range of possible strategies for reducing radon risks to the public, with particular emphasis on two approaches: information and awareness campaigns to encourage testing and remediation by the general public and provision of radon

information at time of home sale. The conclusions that the authors reach as to the relative likehihood of success of these two approaches in actually reducing exposure to radon raise important public policy questions. What should be the role of government in encouraging the public to take actions that are in their own self-interest, but which they do not perceive to be of sufficient importance to bother doing so? Should the government make testing mandatory? If so, for whom, and who should be informed of the results? Should remdiation be mandatory or voluntary? Although the authors do not take positions on all these issues, their research certainly raise all these questions. How these questions are answered is very important not only for public policy but also for the 20,000 or so Americans that the risk analysts now believe die prematurely every year from exposure to radon. If this Report provides a basis for raising these issues and provides information to allow the reader to assess the relative merits of the principal alternatives, it will have done its job.

Alan Carlin

Office of Policy, Planning and Evaluation

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Chapter 1

Introduction and Executive Summary

1.1. Introduction: The Radon Risk Communication Problem

The Environmental Protection Agency (1986a) has estimated that between 5,000 and 20,000 lung cancer deaths per year in the United States can be attributed to exposure to radon gas. Although this level of risk is two to three orders of magnitude greater than many risks that generate public concern and that are regulated by federal agencies, efforts to increase public concern about radon, to promote radon testing, and to encourage appropriate protective responses to radon have thus far been disappointing.

The difficulty in communicating radon risk and promoting radon mitigation may be partly because radon has many risk characteristics that typically lead people to underestimate or to dismiss the risk. The following list summarizes the major risk characteristics that appear to govern radon risk perception:

1. The objective probability of the risk (between 1 and 5% chance of lung cancer for a lifetime exposure to 4 picocuries per liter of radon according to the EPA (1986a)) is below the level where people understand the risk and respond appropriately (Kahneman and Tversky, 1979; Schulze, McClelland, and Coursey, 1986).

2. There are no perceptual cues or reminders to alert people to the presence of the risk (McClelland, Schulze, and Hurd, 1989) since radon is colorless, odorless, and tasteless.

3. The risk is natural as opposed to technological and there is no "villain" to whom one can easily assign blame or responsibility (Baum, Fleming, and Davidson, 1983; Kunreuther, Ginsberg, Miller, Sagi, Slovic, Borkin, and Katz, 1978).

4. People's experience with the risk is typically benign (Schulze, McClelland, and Coursey, 1986) in the sense that they have lived in their homes many years without experiencing any loss due to radon).

5. The effect of the risk is far removed from the initial exposure (radon-induced lung cancer takes many years to develop and displays no early symptoms).

6. Deaths due to the risk are undramatic, occur singly, and are impossible to unequivocally relate to the risk.

7. Exposure to the risk is voluntary in the sense that people choose where they want to live and which home to buy (although only those who purchased homes since radon began receiving public attention in 1986 can possibly have accepted the risk knowingly).

8. The risk is not the same for everyone but varies in complex ways depending on several dimensions (e.g., geographic location, soil type, house structure, occupant behavior).

Studies of radon risk perception have generally confirmed the expectation of lack of concern for radon risk. For example, Sandman, Weinstein, and Klotz (1987) found the most common response to radon to be one of apathy and disinterest, and Johnson and Luken (1987) reported that the perceived risk of their respondents tended to understate the measured objective risk by orders of magnitude. On a more optimistic note, Smith, Desvousges, Fisher, and Johnson (1988) reported some success in communicating radon risk, finding that respondents did adjust their subjective risk perception in the right direction after receiving test results. For a review of these and many other radon studies, see Sjöberg (1989).

It has also been suggested for a wide variety of risks (Adler and Pittle, 1984; Weinstein, 1987) and for radon in particular (Weinstein, Klotz, and Sandman, 1989) that mass media information and awareness campaigns may be unsuccessful in promoting appropriate protective responses to risk. This report includes the first evaluation of such a campaign among the general public for radon, and we will quantify the degree of success of the campaign in promoting radon mitigation and discuss implications for public policy concerning radon and related risks.

This report is organized as follows: The following three sections of this chapter provide an executive summary. The first section provides a brief overview of the empirical findings from two studies: (a) an evaluation of the effectiveness (in terms of ultimate mitigation rates) for an intensive radon information and awareness campaign conducted in the Washington, D. C. area and (b) a survey of recent home buyers in Boulder County, Colorado. The next section provides a conceptual, non-quantitative summary of the findings and provides a framework for characterizing the radon mitigation process that explains, at least partially, our empirical results and leads naturally to several key recommendations. The final section highlights our recommendations for an effective radon mitigation program.

Chapter 2 provides a detailed description of our evaluation of the intensive radon information and awareness campaign. It also presents a model that predicts which homeowners will complete effective radon mitigation actions. Chapter 3 provides a detailed description of the survey of recent home buyers. At issue is the proportion of newly purchased homes that have been tested for radon at or before the time

of the sale and whether effective mitigation actions were taken as a function of radon test results and other characteristics of the real estate transaction. Chapter 4 surveys the legal context for radon mitigation programs consistent with our recommendations which might be instituted or mandated by government. Finally, Chapter 5 presents our conclusions in greater detail and relates them to the empirical findings and the legal context.

1.2. Empirical Findings

This report evaluates alternative strategies for motivating people to test for radon gas in their homes and to mitigate if appropriate. A review of the literature on risk communication and motivating self-protective behavior suggests that traditional information and awareness programs (such as advertising campaigns and public service announcements) are likely to fail when they are targeted at the general population. To test this hypothesis we sent a mail survey to 920 households that had purchased radon test kits as part of an intensive information and awareness campaign in the Washington, D.C. area (see Chapter 2). Over 100,000 test kits were purchased as a result of this campaign. Although we estimate that about 33,000 homes in this area exceed the EPA action level for radon by a factor of five or more (had a radon reading of 20 picocuries per liter or higher), the survey results indicate that only 1.2% of this group have taken convincing remedial action as a result of the campaign. In addition, only about a third of the homes in this 1.2% group conducted a post-mitigation retest to confirm that mitigation had been effective. These homeowners were

sent reprints of two EPA documents, "A Citizen's Guide to Radon" (EPA, 1986a) and "Radon Reduction Methods: A Homeowner's Guide" (EPA, 1986b). Unfortunately, our results suggest that these pamphlets may have encouraged people to try their own remedial measures rather than seek the assistance of a professional contractor. These home remedies (e.g., opening basement windows, sealing foundation cracks) were generally less effective and were not followed by retesting to verify their effectiveness in spite of clear warnings given that single limited remedial measures are likely to be ineffective.

In contrast, a telephone survey of 303 home buyers in Boulder County, Colorado found that over 40% of recently purchased homes were tested for radon gas at the time of home sale and that this testing was often motivated by information provided by the realtor (see Chapter 3). Even though no intensive information and awareness campaign has been conducted in Colorado and there are currently no state laws in effect concerning radon, 54% of tested homes in our sample that had radon levels above the EPA action level underwent mitigation (with 87% of those completing follow-up testing) as part of the home sale transaction. These results suggest that a radon information and awareness program targeted at the point of home sale, when the transaction context provides a strong economic incentive to repair any problems a home might have, could be highly effective in comparison to information targeted at the general population.

EPA is currently limited to supporting information and awareness through such means as its "Citizen's Guide" and "Radon Reduction" pamphlets. Our study suggests that these materials

require substantial revision and that new materials specifically targeted at realtors and homebuyers would be highly desirable, especially in concert with mandatory disclosure.

1.3. Conceptual Summary

Successful mitigation of a radon problem by a homeowner typically requires transition through the stages of buying a test kit, performing the test and sending it to the testing laboratory for analysis, receiving the test results, recognizing a potential problem, performing longer-term follow-up testing, confirming a definite radon problem, taking remedial action, and finally retesting to confirm mitigation effectiveness. If a homeowner fails at any of these steps, effective mitigation will not be achieved. This implies that almost any general information and awareness program, no matter how effectively it is conducted, will fail to achieve a large reduction in population exposure to radon because there are so many opportunities for the homeowner to drop out of the process.

The first and most important bottleneck is getting people to purchase the test kits. Although the absolute number of test kits purchased in the Washington, D. C. campaign was impressive, it still was a small proportion of the households that ought to have tested. Those who did purchase test kits were, compared to the general population, better educated, had higher incomes, owned more expensive homes, and more often had children. It may be very difficult for a general information and awareness campaign to reach the larger population which does not have these characteristics.

Another major bottleneck is that when residents were notified of high radon levels they often failed to take action or they took action that was ineffective. It appears that the current radon brochures sent to the residents may have inadvertently misled them to believe that opening a window or sealing a few cracks would be effective in reducing radon levels greater than 20 pCi/l.

It is easy to suggest a number of improvements that might achieve appreciable increases in transition rates at each stage of the mitigation process. For example, brochures aimed at those with high radon levels could be rewritten with more specific mitigation recommendations. Also, the testing company could follow the example of survey researchers and send reminders as a follow-up to the initial test results. If major improvements were made at all the steps it might be possible to improve the effective mitigation rate five-fold so that the general campaign might at least be cost effective. However, the initial bottleneck of getting enough people to participate would still likely remain.

The results for presenting radon information at the time of home sale are more encouraging. This suggests that a program focused at time of home sale might be appreciably more effective than a general awareness campaign. Probably the most effective strategy would be to require through regulation that all homes be tested at time of sale and the test results be disclosed to all interested parties. If regulation is not feasible, we recommend a program aimed at realtors, lenders, and others involved in home sale transactions. This would require a revised brochure and an information campaign tailored for realtors and home buyers. The effectiveness of such a

program would be higher but slow because of the time it takes for the housing stock to change ownership. However, in the long term it probably would end up being much more effective than an information and awareness campaign aimed at the general population.

Our results are generally consistent with experience from attempts to motivate people to take protective action with respect to other risks. For example, general awareness and information campaigns to get people to wear seat belts have generally been ineffective in increasing voluntary use of seat belts. As a consequence, more and more jurisdictions, both in the United States and elsewhere, are turning to regulated, mandatory use of seat belts. There is nothing in the literature nor in our data that suggests any other solution for radon will be ultimately as effective.

In summary, our recommendation for increasing effective radon mitigation is (a) develop information and awareness materials to be distributed, perhaps by realtors or lending agencies, to home buyers at time of house purchase, and/or (b) require radon testing and disclosure of information about potential radon hazards at time of home purchase. This recommendation is detailed in the next section.

1.4. Recommendation

This study attempts to integrate three often disparate viewpoints - psychology, economics, and law -- within the context of addressing radon pollution. Based on the results detailed in the following chapters, we believe it is possible to combine these three

disciplines to devise an effective strategy to address radon contamination in homes.

From a psychological perspective the main policy question is under what circumstances (if any) will people respond to warnings about radon. This study shows that general information campaigns, when used alone, fail to accomplish radon reduction but that radon information provided at a key point in time, during the home sale transaction, gets the attention necessary to mitigate radon levels. Study results also indicate that social diffusion of radon information to the public through realtors, employers, mortgage bankers, and contractors may be effective.

From an economic perspective, we have determined that general information campaigns alone do not appear to be cost effective. Economic incentives, on the other hand, can encourage protective behavior but require consumers to be aware of the problem; in order to be effective, the incentives must be founded on information and awareness. Additionally, incentive programs must be carefully designed to avoid inefficiency or bias. Also, the potential cost to the federal government can be a major problem with incentives.

From a legal perspective, either incentives or regulation may provide an avenue for addressing the radon problem. As pointed out above, incentives can be costly and inefficient. It also may be difficult for the federal government to "police" incentives such as tax credits to ensure that they are put to their intended use. General regulatory strategies can suffer the same defects as incentive strategies. Nevertheless, our research suggests that effective regulations can be formulated by using the results of this study to design a regulatory

strategy aimed at the home sale transaction. This strategy would require mandatory disclosure of radon level at time of home sale.

A home sale transaction strategy has certain drawbacks. First, it cannot address all radon contamination because it does not cover all dwelling units. For example, people who rent rather than own would not be affected by this strategy, although the owners of their dwellings would be. Second, it is a relatively slow approach. Because only about 5% of all homes are sold each year it might take as long as 14 years to reach one half of all the currently existing homes. Third, it may be inequitable. Its costs may fall hardest on the current owner/seller of the home who may be required to test and mitigate a condition that he did not create nor to which he contributed.

However, the home sale transaction regulatory strategy exploits a key event - the decision to purchase a home - to focus the attention of the home sale participants (e.g., buyer, seller, mortgage banker, realtor) on the potential health effects of radon contamination. During the home sales transaction, buyers and sellers are focused on the condition of the home. Buyers are anxious to learn as much as possible about the property. Sellers are likely to commit resources to correct any perceived defects.

The home sales transaction strategy requires that before the closing, radon tests be conducted, and their results obtained and disclosed, to all participants in the home sale transaction. It takes advantage of the psychological principles outlined in this report by providing information about radon levels in a timely fashion such that protective behavior is framed as part of a high profile, single decision that covers a long time span. It also uses existing channels of social

communication to disperse information about radon by involving mortgage bankers and realtors in disseminating radon information.

The home sales transaction strategy also is economically efficient. Because the burdens of testing, disclosure, and mitigation are imposed upon the participants to the home sale transaction, the federal government will not be forced to provide testing services or offset costs of remediation. Since the buyer, realtor, and mortgage banker have a strong self-interest in learning about radon, the strategy is to a large extent self-policing. Additionally, because the strategy does not require mitigation, it will allow the buyer and seller to negotiate for remediation of radon pollution, if necessary. Evidence suggests that the result of such negotiations will almost always be to remediate rather than compensate the buyer for accepting the risk. Thus, free market economic forces shape the ultimate resolution of the radon problem.

In order to implement this strategy, the Congress must enact legislation empowering a federal agency such as the Environmental Protection Agency to promulgate regulations requiring radon testing and disclosure of test results during the home sale transaction. Some of the potential legal impediments to such legislation are reviewed in Chapter 4. Traditionally, the federal government has not intruded into home sale transactions, although it has enacted at least one law requiring disclosure of certain closing costs in home sales financed by "federally related mortgages."

Chapter 2

Evaluation of an Intensive Radon Information and Awareness Campaign

2.0. Chapter Summary

This study analyzes the effectiveness of a mass media radon information and testing campaign conducted in the Washington, D. C. area in the Winter of 1988. Although an impressive number of test kits (approximately 100,000) were sold, the ultimate mitigation rates resulting from the campaign were extremely low. Analyses show that low mitigation rates cannot be explained by postulating that people's responses to radon are insensitive to the level of objective risk, but instead are due to characteristics of the protective response required to reduce radon risk. Radon may be thought of as one of a family of intractable risks with risk response profiles that make them particularly difficult for people to manage and remediate. Traditional information campaigns for such risks are likely to fail; instead they may require regulatory strategies or programs that provide active guidance and assistance throughout the remediation process.

2.1. Introduction

The literature on radon risk perception and the particular difficulties of communicating the risks of radon exposure are briefly summarized in Chapter 1. Although the importance of these risk perception issues is recognized, the focus in this study is on radon mitigation. The respondents in this study have at least partially overcome the perceptual obstacles detailed above to make a voluntary decision to test for radon and have received the radon test results for their home. The findings reported below detail their behavioral responses to receiving these test results.

Our discussion of these responses will focus on three major issues. First, it has been suggested for a wide variety of risks (Adler and Pittle, 1984; Weinstein, 1987) and for radon in particular (Weinstein, Klotz, and Sandman, 1989) that mass media information and awareness campaigns may be unsuccessful in promoting appropriate protective responses to risk. This study represents the first evaluation of such a campaign among the general public for radon, and we will quantify the degree of success of the campaign in promoting radon mitigation and discuss implications for public policy concerning radon and related risks.

Second, given a population of people who have tested for radon, we will examine what variables predict who among them will mitigate and who will not. Of special interest is the relationship between radon level and mitigation. Johnson and Luken (1987) reported mitigation to be independent of exposure level, whereas Åckerman (1988) found

probability of mitigating to increase with increasing initial radon reading. A third study conducted by Weinstein, Klotz, and Sandman (1989) concluded that mitigation depends not on the precise radon level, but only on whether this level is above or below the EPA "action level" of 4 picocuries per liter (pCi/l). Because we had available a database of 55,380 returned test kits, the present study is the first to be able to oversample high radon levels and should provide greater statistical power for examining the relationship between radon level and mitigation behavior than previous studies.

Finally, we will build on the results of the first two analyses to analyze the mitigation process and develop a profile of characteristics of the protective response to radon (and related risks) which we feel governs mitigation responses just as the risk characteristics listed in Chapter 1 appear to govern risk perception responses.

It should be emphasized that the respondents to this study were not recruited to participate in a radon study, but were contacted only after receiving their voluntarily requested test results and having on average nine months to make mitigation decisions. They faced a real risk from radon and made actual mitigation decisions concerning their own homes.

2.2. The Washington, D. C. Radon Campaign

The Washington, D. C. information and testing campaign constitutes the largest and most successful mass media campaign for radon to date and likely represents the best result that can be achieved from a campaign of this type. The campaign was a

cooperative effort between WJLA-TV, a Washington, D.C. television station, Safeway foodstores, and Air Chek, Inc., a North Carolina company that sells and analyzes radon test kits (charcoal canisters). During the campaign (conducted in January and February of 1988) radon test kits could be purchased at 125 Safeway stores at a 50% discount ($4.75 selling price) or by using a discount mail coupon that appeared in a full-page one-shot ad in the Washington Post. In addition, the usual postage and processing fees required to obtain test results were waived by Air Chek. This promotional offer was featured during a consumer affairs news segment called "Radon Watch" on WJLA-TV, which began with a three-part series on January 2 and ended with a second three-part series the week of February 15. According to the A. C. Nielson company, WJLA-TV reaches about 1.5 million households in Washington, D. C., Virginia, and Maryland. The total number of test kits sold during the campaign was approximately 100,000, representing about 6.5% of the target population. This level of participation is extremely high for a media campaign aimed at the general population. However, as we shall describe below, purchasing a test kit only rarely results in eventual protection against radon risk.

Along with their radon test results reported in picocuries per liter, all those who returned test kits to Air Chek received a two-page letter. The letter briefly explained their test results and made suggestions for follow-up action which generally corresponded to those in the EPA publication "A Citizen's Guide to Radon" (EPA, 1986a). Those with readings above 4 pCi/l received additional information that varied depending on which of three intervals their test results fell into. Those with readings between 4 and 20 pCi/l

were sent a reprint of the "Citizen's Guide." The Citizen's Guide is a 16-page pamphlet that gives basic information about radon and radon detection and makes suggestions for protective action which vary according to radon level. Those with readings between 20 and 50 pCi/l were sent the Citizen's Guide as well as a second EPA publication titled "Radon Reduction Methods: A Homeowner's Guide" (EPA, 1986b). The "Homeowner's Guide" is a 24-page pamphlet which describes and compares nine basic techniques for radon reduction, ranging from inexpensive natural ventilation to more costly methods such as forced ventilation and sub-slab suction. Those with readings greater than 50 pCi/l received a letter urging an immediate retest accompanied by a free retest kit. The interval limits of 4 and 20 pCi/l correspond to the limits of intervals for which the EPA recommends different actions in their Citizen's Guide. The interval limit of 50 pCi/l was chosen by Air Chek as part of their standard testing procedure.

2.3. Survey Methodology

2.3.1. Sample Design

In November and December of 1988 we conducted a mail survey of a sample of participants in the Washington, D. C. area campaign. The sampling frame consisted of all radon test kits returned to Air Chek for processing having serial numbers in a particular range which identified them as coming from program participants. There were 55,830 such kits.

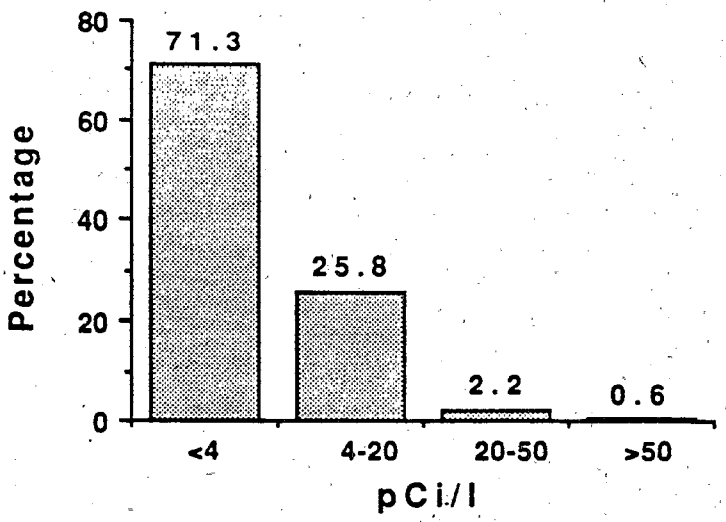

Fig. 2.1. Percentage of the population of Air Chek test kits falling into each radon level category.

Figure 2.1 shows the proportion of the population of test kits falling into each of the four radon level intervals described above. The distribution of radon test results is of course very skewed with over 70% of the readings less than 4 pCi/l and only about 3% greater than 20 pCi/l. A simple random sample from this population of test kits would clearly yield few kits with high radon levels. Thus, a stratified sampling design was used to ensure adequate numbers of observations to allow separate estimates of mitigation rates at each radon level. We randomly sampled 250 test kits from each of the four intervals defined above. After removing duplicates (many households purchased more than one test kit) and commercial and government addresses, we had the distribution of households shown in Table 2.1. There was a greater loss of usable addresses at the higher radon levels because for

Table 2.1. Distribution of Households in Sample by Radon Level

Radon level (pCi/l)	Households in sample
<4	248
4-20	241
20-50	229
>50	202
Total	920

those levels we were sampling a much larger proportion of the population (e.g., over 75% of the test kits with radon levels greater than 50 pCi/l) and duplicates were therefore more frequently encountered. Surveys were mailed to all remaining 920 good addresses.

3.2. Survey Design and Implementation

The survey was prepared according to the Total Design Method described by Dillman (1978) and was mailed and collected by the testing company, Air Chek. Recent research has indicated that prepaying respondents increases response rates (Berk, Mathiowetz, Ward, and White, 1988). So, in addition to the standard reminders commonly used to increase response rates, we included a two dollar

bill in the initial mailing. The cover letter explained that the money was being given to help compensate participants for their time and efforts in filling out the survey. This approach yielded a response rate of just over 77%. The response rate did not vary by radon level.

The survey questionnaire was a twelve-page booklet containing 59 questions, although only 36 questions applied to all respondents. The questionnaire assessed respondent's general experience with radon and asked questions about their radon test, their test results, and their reactions to the test results. In addition, respondents who indicated they had taken action to reduce their radon levels were asked detailed questions about their mitigation experience, including which specific reduction methods they used, who actually did the mitigation work, how much money they spent on mitigation, and whether they had performed a retest to confirm mitigation success. The questionnaire also included the standard sociodemographic questions as well as a few questions about characteristics of their home and their behavior toward other risks (smoking and wearing seatbelts). A facsimile of the survey instrument used in this study is presented in Appendix I, including results for each question by radon level category.

2.3.3. Characteristics of the Population

Before proceeding to our analyses of the survey, it is worth describing here several characteristics of the population of people who returned test kits to Air Chek. The results below are estimates based on sample data that have been weighted to correct for the

oversampling of higher radon levels described above. Results showed the population to be highly educated (62% achieving at least a four-year college degree) and relatively wealthy (76% having an annual household income before taxes of more than $40,000). The overwhelming majority of people (94%) own their own homes, and 82.8% of all residences are single-family detached homes. The average age of the population is 47, and 62% are male.

Like virtually all research on radon to date, the population of testers is clearly more educated and wealthier than average and almost exclusively own their own homes. Also, test kits are more likely to be sent in by a male than a female. This survey does not address how people with low incomes, people with limited education, or people who rent rather than own respond to radon.

2.4. Evaluation of the Washington, D. C. Area Campaign

2.4.1. The Pathway to Mitigation

The ultimate goal of any radon risk communication program is to get those households in need of mitigation to mitigate. Therefore our evaluation of the Washington, D. C. campaign will be based on estimating what percentage of households in the target population with maximum radon readings above the EPA action level of 4 pCi/l mitigated as a result of the campaign.[1] To estimate the ultimate

[1] There is quite a bit of controversy over what level of radon indicates an unequivocal "need for mitigation." The Environmental Defense Fund, for example, claims the EPA action level is too high and recommends indoor radon levels be reduced to the level of outdoor background radiation (0.2 pCi/l) (Yuhnke, Silbergeld, and Caswell, 1987). Others claim the EPA has greatly overestimated the risk and

mitigation rate we will estimate the percentage of the target population surviving at various identifiable stages along the pathway to successful mitigation. This will also allow us to compare transition rates between stages to identify those stages that may be especially troublesome for a radon campaign.

Figure 2.2 illustrates the uncertain, multistage pathway to mitigation. Clearly households in the target population that need mitigation can drop out of the pathway short of success at several different stages. Stage 1 is the purchase of one or more radon test kits at participating Safeway stores. If a household does not purchase a test kit, then it will not mitigate as a result of this campaign, although mitigation may occur through other routes not associated with this particular risk communication effort.

Stage 2 is actually conducting the radon test. Many people may purchase a test kit but not actually conduct the test. Or, they may

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recommend no action at any level until further epidemiological studies have been completed (Cole, 1990). In our campaign evaluation we have chosen to define those households with readings greater than the EPA action level as "needing mitigation" because of the widespread adoption of this level as a standard by state agencies, testing companies, mitigation contractors, realtors, and homeowners. (Although EPA did not originally intend the action level to be interpreted as a standard, it has become one in practice, largely because no other is available. It may not in general be possible for risk communicators to communicate precise risk levels without them being interpreted as standards by the public.) In any case, as shown in Fig. 2.3, ultimate mitigation rates are very low at all radon levels. Our evaluation of the effectiveness of the campaign is therefore relatively insensitive to the precise definition of "need for mitigation."

In addition, we have made the simplifying assumption that the level indicating a need for mitigation is the same for all households, which may not be the case. For example, people who spend little time in their basements might have less of a need to mitigate a given basement level reading than people who spend more time in their basements.

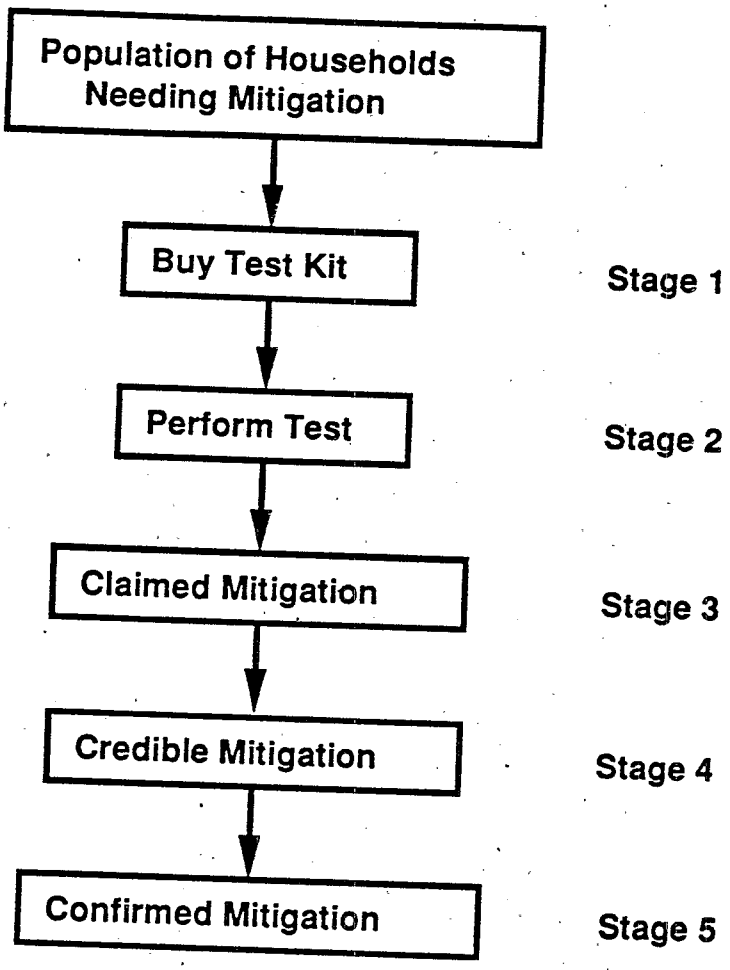

Fig. 2.2. The pathway to radon mitigation conceptualized as a multistage process. This pathway is simplified in the sense that each stage may have several substages and stages may, during actual implementation, be cycled through several times. For example, current EPA recommendations recommend longer-term testing after an initial short-term test for test results between 4 and 20 pCi/l.

place the kit in the basement but forget to send it to the testing company for measurement of the radon level. Our operational definition of "performing the test" is returning a test kit to Air Chek for evaluation.

The final three stages encompass the process of carrying out some mitigating action or actions once a high radon test result has

been received from the testing company. In our survey there were several possible operational definitions of mitigation. The simplest definition is to use responses to the question, "Have you taken action to reduce radon levels in the home which you tested?" An affirmative response to this question constitutes Stage 3 (claimed mitigation) in our analysis.

However, there are problems with accepting self-reports of mitigation. First, there may be a social desirability effect. People may have been embarrassed to admit to the testing company who sent them their results that they had taken no action to reduce their radon level. Second, people may have taken actions that are legitimate but ineffective efforts to reduce their radon level. For example, many respondents in our survey reported attempting to reduce radon levels by leaving their doors and windows open more frequently. We therefore added another stage to the mitigation pathway. If someone mitigated effectively, it is reasonable to expect them to respond with a dollar amount greater than zero to the question, "About how much have you spent on radon reduction?," and to be able to identify the specific category of reduction method that was used (e.g., sealing, ventilation, filtering, pressurization) from a list of possible options. This is our operational definition of Stage 4 (credible mitigation).

Finally, attempting mitigation in a credible manner is not the final stage in ensuring protection against radon risk. To verify that mitigation has been successful, a post-mitigation retest should be performed. An affirmative answer to the question, "Have you had your home retested for radon since completing your radon reduction

efforts?," is therefore our operational definition of Stage 5 (confirmed mitigation).

The next section details how we arrived at estimates of the transition rates between the stages on the pathway to mitigation for each radon level category. However, it should first be noted that for a multistage process such as the mitigation pathway we have described only a relatively small proportion of the population will survive to the final stage. For example, even if the transition rates for each of the five stages were about 50%, then the final proportion reaching Stage 5 would be only about 3%. If the transition rates were about 85%, an unreasonably high expectation, the ultimate confirmed mitigation rate would still be only about 44%. Because these observations led us to expect a very low ultimate confirmed mitigation rate, we tried to make assumptions, when necessary, which would err on the side of favoring the effectiveness of the program.

2.4.2. Estimation of Transition Rates and Population Proportions

2.4.2.1. Number of Households Needing Mitigation

First we need to estimate the total number of households in the population targeted by the Washington, D. C. area campaign. According to the A. C. Nielson Co., the viewing area of television station WJLA contains approximately 1.5 million households. Although census data for the Washington, D. C. and Baltimore metropolitan areas indicates the total number of households to be approximately 1.9

million, we will use the conservative estimate of 1.5 million households that could potentially have participated in the program.

Our sample of testers consisted primarily of residents of single-family, detached homes (90.9%). Although radon is not necessarily just a problem of single-family homes, it is more likely to be a problem for such residences than it is for multi-unit condominiums or apartment buildings, and residents of single-family homes are more likely to have the authority to implement effective mitigating actions. It therefore seems reasonable to restrict our analysis to only the population of single-family homes in the target area. From census data the average proportion of single-family homes in the Washington, D. C./Baltimore area is approximately 62.2%. We therefore reduce our original estimate of 1.5 million households to 933,630 single-family homes.

Finally, in order to determine how many of these homes need mitigation, we must estimate the proportion that fall into each radon level category. We know the proportion of radon test kits returned to Air Chek which fell into each category. However, these proportions might underestimate the actual proportions because many households may have purchased more than one test kit and placed them in different areas of their homes (for example, one in the basement to get a maximum reading and one in an upstairs bedroom to get a minimum reading). We also have available a self-report of radon level from respondents to the survey. However, simply using self-reports might also underestimate the actual proportions in each category due to people's tendency to underreport their true radon reading (see Section 2.6). In the following analysis we chose, as the best available

indicator of whether a household needs to mitigate, the maximum radon reading obtained from any test kit. [2] We attempted to estimate this from our survey by using the maximum radon level for the household reported by either the respondent (for any test results they received) or by Air Chek (for the test kit selected in the sample). [3] Weighted estimates [4] of the population proportions for each radon level are shown in Table 2.2. [5] The estimated number of households needing mitigation (having a maximum radon level above 4 pCi/l) is 381,714 (40.88%).

2.4.2.2. Percentage of Households Purchasing Test Kits

Next we need to estimate the percentage of households needing mitigation who purchased test kits from Air Chek. The test serial

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[2] The substantive conclusions of the campaign evaluation are in fact the same no matter which measure of radon level (the Air-Chek reading, the self-report, or the maximum available) is adopted.

[3] Eighty-eight percent of our respondents reported obtaining a basement-level reading, so their test results generally represent the maximum reading likely to be obtained in the home.

[4] The weighting adjusts for the oversampling of higher radon levels as described in Section 2.3.1.

[5] There are several factors that may make our estimated proportions for higher radon levels unrealistically elevated when compared with other estimates for the Washington, D. C. area. First, by restricting to single family homes we may have restricted the sample to dwellings more likely to have higher radon levels. Second, areas in which higher radon levels were suspected, either due to press reports or tests conducted by neighbors, may have had higher participation rates. Third, even slight variability in testing reliability could put some of the large number of households with true radon levels of slightly less than, for example, 4 pCi/l, into the next higher category. It should be noted, however, that our estimated proportions for the two highest radon level categories are not appreciably different from the proportions in the population of test kits (see Section 2.3.1).

Table 2.2. Estimated Households in Target Population by Radon Level

Maximum radon level (pCi/l)	Percentage	Estimated households in population
<4	59.12%	551,916
4-20	37.38%	348,958
20-50	2.77%	25,894
>50	0.73%	6,862
Total	100.00%	933,630

numbers indicate that approximately 100,000 test kits were sold as part of this particular campaign. We must first reduce this estimate of total households purchasing to 90,900 single-family homes, representing the 90.9% of our sample.[6] However, survey responses indicate that on average each household purchased 1.5 test kits. Thus we need to divide the 90,900 homes by 1.5 to obtain the estimate of approximately 60,600 single-family homes purchasing test kits.[7]

[6] There was a slight tendency for tests with lower radon levels to be more likely to come from non-single-family homes. Thus the 90.9% estimate of the percentage of single-family homes from our sample is reduced to 82.8% when weighted to account for oversampling of higher radon levels. Using the 90.9% estimate might overestimate the number of testers and therefore make the program appear slightly more effective.

[7] It is possible that people who returned test kits were more likely to have purchased more than one test kit, in which case the estimate of 60,600 homes would underestimate the true number of

Dividing 60,600 by the number of single family homes in the target population yields an estimated transition rate of 6.5% of households purchasing test kits. Only 24,811 of the 381,714 houses needing mitigation reached this stage.

2.4.2.3. Percentage of Households Actually Testing

We must now estimate the percentage of households that actually conducted the radon test given they purchased a test kit. We begin with the 55,830 test kits returned to Air Chek for evaluation. Multiplying this number by 90.9% reduces the estimate of single-family homes actually testing to 50,750. The weighted estimate from the survey responses of 1.5 test kits per household does apply to the population of returned test kits.[8] Thus the estimate of the transition rate from purchasing (Stage 1) to testing (Stage 2) is 33,833/60,600 = 55.8%. [9] Only 13,845 of the 381,714 homes needing mitigation tested.

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households purchasing test kits. This is not a serious problem, however, because we do have a firmer estimate of the number of households testing. Thus, changing the estimate of households purchasing (Stage 1) would not affect the estimate of the overall transition rate from the population to Stage 2.

[8] There was a slight trend for households with higher radon levels to report having purchased more test kits. If this is indeed the case, then using a common estimate of number of kits purchased would slightly overestimate the number of households with high radon levels who purchased kits and actually tested. Again, this error would be on the side of making the program appear slightly more effective.

[9] Air Chek reports that they typically receive for analysis a much higher proportion of the test kits which they sell (over 90%). Apparently many of the people responding to the campaign are purchasing radon test kits on impulse and these people are much less likely to actually perform the test than people who purchase on their own initiative.

2.4.2.4. Percentage of Households Mitigating

Finally, we can estimate from our survey responses, for each radon level category, the proportion of testing households that went on to mitigate. Table 2.3 shows these proportions for each of the three mitigation stages we have defined: claimed, credible, and confirmed. The proportion of households claiming mitigation increases dramatically with radon level, going from 11.9% for the 4-20 pCi/l category to 52.5% for the >50 pCi/l category. We test the reliability of this relationship in Section 2.5.

The proportion of testers who mitigated in our study, even by the very liberal standards we used to define the "claimed mitigation" category, is quite low compared to the results of two previous studies. Weinstein, Sandman, and Roberts (1988), for example, reported the mitigation rate for a population of 123 New Jersey homeowners to be 62% even for radon readings as low as 4-8 pCi/l (these were living room readings, as opposed to basement readings, and therefore may not represent maximum radon readings). Also, Åckerman (1988) reported mitigation rates as high as 38% at 12.5 pCi/l and 62% at 50 pCi/l for a population of testers in a suburb of Stockholm, Sweden. The major difference between these two studies and the present one appears to be the amount of outside help received by testers from a governmental agency. In the New Jersey study, participants received free testing and advice from the New Jersey Department of Environmental Protection's confirmatory radon monitoring program. In the Stockholm study, tests were conducted by the local health department for a fee of $65, and those with a high radon reading

Table 2.3. Proportion of Sample Households Mitigating by Radon Level

Maximum radon level (pCi/l)	Proportion of population mitigating		
	Claimed	Credible	Confirmed
<4	4.7%	2.7%	0.0%
4-20	11.9%	5.5%	1.8%
20-50	43.4%	32.0%	10.3%
>50	52.5%	40.4%	19.6%

received free retesting and mitigation advice from the department. In our study, participants received printed information produced by Air Chek and the Environmental Protection Agency, but had no personal contact with EPA or any other government agency or mitigation firm unless they had initiated the contact. Apparently mitigation rates for homeowners who test on their own initiative and receive only minimal assistance from outside agencies during the testing and mitigation process are especially low.

The decrease in the proportion of households mitigating in a credible way and confirming mitigation success illustrate the importance of defining "mitigation" carefully. For example, for the 4-20 pCi/l category, only 46% of those claiming mitigation reported spending money on mitigation and could report the specific mitigation method that was used, and only 15.3% of those claiming mitigation reported retesting after mitigating.

Although the three mitigation categories we have defined are not necessarily (but often may be) separate stages for each individual, they can be analyzed as separate stages in the mitigation process for the population as a whole. Of the 13,845 homes in the target population which needed mitigation and actually tested, only 2043 (14.8%) claimed they had mitigated, only 1093 (7.9%) mitigated "credibly," and only 376 (2.7%) retested to confirm mitigation success.

2.4.3. Campaign Evaluation

Figure 2.3 summarizes our evaluation of the Washington, D. C. campaign and includes absolute population estimates and transition rates for each stage in the mitigation pathway and for each radon level category. As expected, the ultimate confirmed mitigation rates are very low. This is an inevitable consequence of any multistage process in which one or more transition rates may be low. Of the 381,714 single-family homes in the target population which needed mitigation, only 376 remain at the final stage of the process. This yields an overall confirmed mitigation rate of just under .1%. The overall rate of .1% improves only to .29% if the "credible" definition of mitigation is considered sufficient and only to .54% if the "claimed" definition of mitigation is considered sufficient. Even for the highest radon level category, >50 pCi/l, the ultimate confirmed mitigation rate is only .7%, and this improves only to about 2% for the liberal "claimed" definition of mitigation.

The transition rate going from the population of households to purchasing a test kit was 6.5% for this program, which is a very

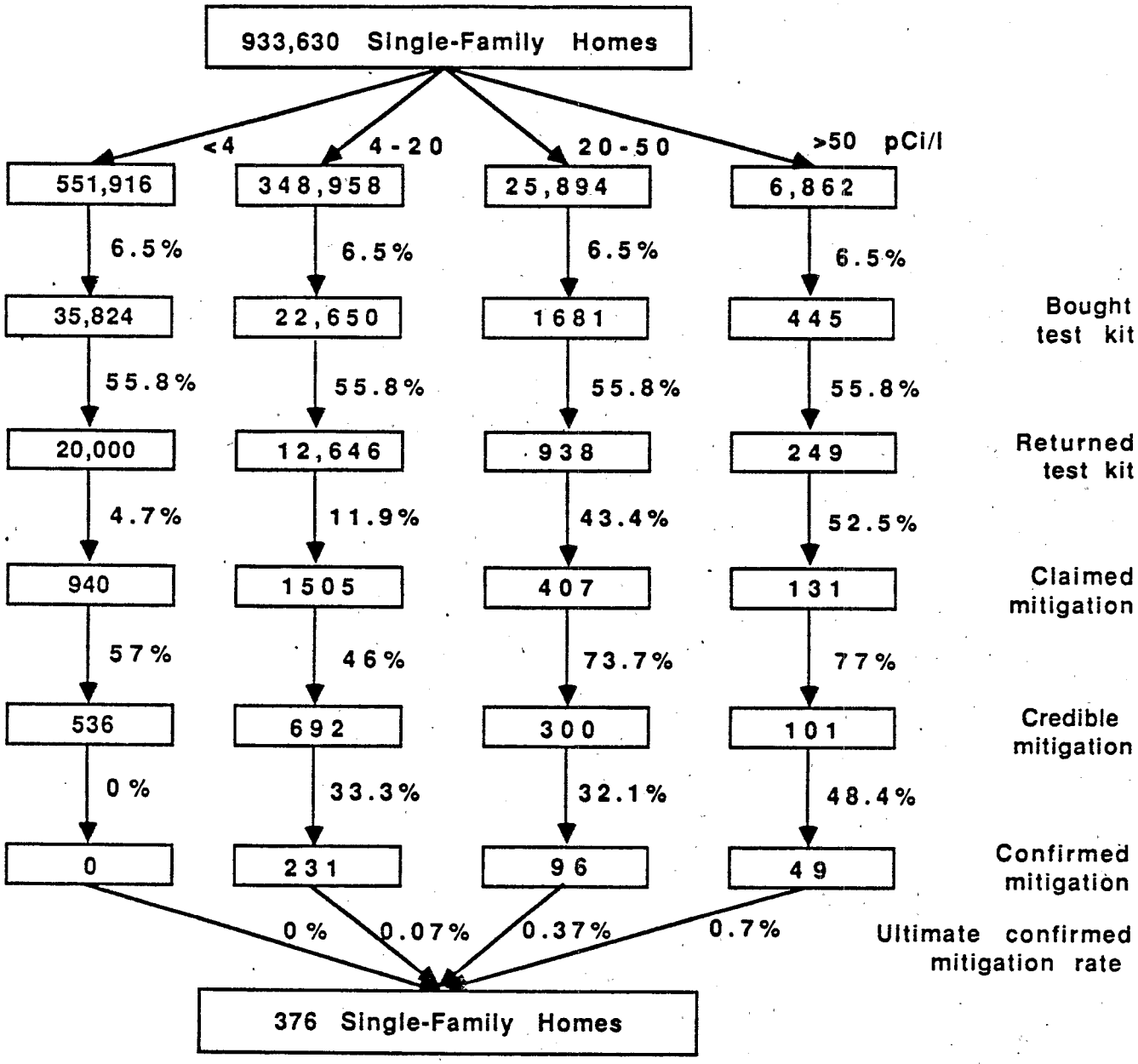

Fig. 2.3. Summary evaluation of the Washington, D. C. campaign showing population estimates and transition rates for each stage in the mitigation pathway, by radon level category.

impressive participation rate for a mass media campaign aimed at the general public. However, this means that, for example, out of the 6,862 homes with extreme radon levels (>50 pCi/l), only 445 purchased a test kit. The vast majority of homes with extreme levels therefore remained undetected. Even so, if this 6.5% of the population were now protected against radon risk as a result of the campaign, the Washington, D. C. program might be considered a success. The subsequent transition rates, however, demonstrate that this is not the case. Only just over half of those who buy a test kit actually return it for processing. Only about half of those who get test results in the highest categories take even simple mitigation actions such as opening windows more often. Overall, even for the highest radon level categories, from 20 to 60% of the population drops out of the mitigation process at each of several stages. Clearly, protecting oneself from radon risk is a long and difficult process for many people, and only a very few stick with it to the very end.

Of particular concern are the transition rates after purchasing a test kit for the 4-20 pCi/l group. Only 11.9% of those receiving test results in this range even claim to mitigate, only 46% of those who claim to mitigate do so in a credible fashion, and only a third of those who mitigate credibly do a confirmatory retest. Considering that over 90% of all households which need mitigation fall into this category, these rates are alarmingly low.

Even given these low transition rates, however, the highest absolute estimated number of households mitigating fall into the 4-20 pCi/l category. This is because the base population to which these transition rates apply is so much larger than the base populations for

the higher categories. Taken a step further, the category with the largest base rate is <4 pCi/l. We estimated that 940 households in this category claimed to have mitigated, yielding the rather paradoxical result that fully one-third of all those who claim to mitigate do not even need to mitigate at all according to EPA guidelines.[10] It is an inevitable consequence of screening for low-probability events (in this case, very high radon levels) that the absolute numbers taking action in the rare categories, where action is most needed, will be relatively low, and that the absolute numbers taking action in more frequent categories, where action is less critical, will be relatively high.

In constructing the estimated transition rates and proportions above we tried to make assumptions that would be favorable to the evaluation of information and testing programs for radon. However, this was not always possible. It is, in fact, probable that, although the campaign we studied represents a state-of-the-art mass media public information effort for radon, more localized public information campaigns would be somewhat more effective. In fact, a more localized and effective radon information campaign has been conducted in Frederick, Maryland by Desvousges, Smith, and Rink (1988). This effort integrated media messages with a community outreach program which included presentations to community

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[10] It would be a mistake to conclude that all those who mitigate after receiving test results less than 4 pCi/l are acting irrationally, although some may be. First, a reading of 3.9 pCi/l, for example, does not represent substantially lower risk than a reading of 4.1 pCi/l. Also, the EPA action level may still represent a substantial risk of lung cancer (between 1 and 5%) over a 70-year lifetime. Finally, these people may feel they are taking preventive measures against the development of a radon problem in the future.

organizations, placement of posters at various community locations, and a "radon awareness week," and achieved a testing rate in Frederick of about 15%. However, if we replace the 3.6% testing rate from our study with the 15% testing rate from the Frederick campaign in our multistage analysis, our ultimate confirmed mitigation rate increases only from .1% to .42%.

It is also possible that more mitigation may occur in the future as a result of the Washington, D. C. campaign, especially given the advice in the EPA Citizen's Guide to the effect that levels between 4 and 20 pCi/l require action only "within a few years."[11] Our respondents typically had about 9 months between the time they tested and the time we contacted them to fill out the survey. However, on the survey we asked respondents the specific month and year in which they first tested their home for radon. There was, in fact, substantial variability in the answers to this question: a few people evidently had conducted a non-Air Chek test long before the campaign, and others clearly waited several months after buying their Air Chek test kit to perform the test and send it in. If in fact the proportion of those mitigating is increasing over time, the length of time passed since their first test should be a reliable predictor of whether or not they mitigated. We tested this predictor in the context of the full mitigation model

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[11] Although it is true that for test results in this range the risk does not increase substantially over a wait of a few years, our results suggest that advising people to take action only within a few years is a misguided risk communication message. Given the multistage nature of the mitigation process, if people don't take action to protect themselves from radon immediately, they are unlikely to do so at all.

developed in Section 2.5 and found it to be nonsignificant (t = -.04, n.s.).

Although we have no evidence that mitigation is increasing over time, it is possible that people are waiting for the results of confirmatory retests, as is recommended in the Citizen's Guide, before proceeding with mitigation. However, only 19% of those in the 4-20 pCi/l category (which comprises 90% of households which need to mitigate) who did not claim to have mitigated stated that they had performed or were conducting a follow-up test. Also, only 46% of those in the >50 pCi/l category who did not claim to mitigate had conducted a follow-up test, even though all of these people had received a free retest kit from Air Chek. Even if all of these people went on to eventually claim mitigation, in the 4-20 pCi/l category, for example, the ultimate confirmed mitigation rate would increase only from .07% to about .2%.

Still another possibility is that there may be many people who wanted to mitigate but were unable to find qualified contractors to do the work. However, in our sample, those who mitigated and used a contractor gave a mean rating of 3.8 on a 1 to 7 scale to the question, How difficult was it to find a trustworthy radon reduction contractor? Finding a radon contractor is clearly not extremely easy, but neither is it extremely difficult. Although at least some future mitigation will occur, given the ease with which people tend to forget about radon, we view extensive future mitigation attributable to this campaign as highly unlikely.

A final concern to our analysis is that our estimate of the transition rate between the population needing mitigation and those

buying test kits may be too low. For example, our estimate of the number of households needing mitigation undoubtedly includes some households that tested and mitigated on their own or through other sources. Also, many of the Safeway stores participating in the campaign sold all of their test kits. Although some of this excess demand was met through a newspaper ad, it is possible that there were many people who wanted to buy a test kit but couldn't. However, even if our estimate of the transition rate to buying a test kit were too low by an order of magnitude, the ultimate confirmed mitigation rate for those homes needing mitigation would only be 1%. Our conclusion concerning the ineffectiveness of the campaign is relatively insensitive to the precise estimates we have described.

The extremely low ultimate mitigation rates resulting from the Washington, D. C. area campaign provide convincing evidence that not only this particular campaign was ineffective but that any radon campaign targeted at the general population which relies only on information, awareness, and voluntary testing is likely to fail. At the very least, the likely credible mitigation resulting from this program has been so small as to suggest that such programs may be a very expensive way for society to achieve radon mitigation.

Although many factors likely contribute to this result, the major one appears to be the multistage nature of the radon mitigation process, which requires many varied actions be performed over a long period of time and provides opportunities to drop out at any of several stages. The majority of people simply do not make it all the way to the end (or even to the middle) of this complex process by themselves.

This result also raises serious questions for public policy concerning radon. If information and awareness campaigns including economic incentives do not achieve reasonable levels of mitigation, the options for public policy are limited. One solution would be to adopt a mandatory radon testing and mitigation law similar to many recent state laws which require the use of seatbelts and child-restraint devices in automobiles. A second solution would be to require radon disclosure at a particular point in time during which radon testing and mitigation might be easier than usual, during which there may be strong preexisting incentives for making a home risk-free, and during which people would be available to provide homeowners active guidance throughout the mitigation process, as part of their professional responsibilities. The time of home sale fits this description quite well. In a survey study conducted in Boulder, Colorado (see Chapter 3) we found that the ultimate credible mitigation rate for a subpopulation of people who had recently gone through the process of buying a home was over 21%. This high ultimate mitigation rate was found in an area in which radon has received little media attention and there exist no state laws concerning radon disclosure, and in a sample with maximum radon readings below 20 pCi/l. In contrast, the ultimate credible mitigation rate found in the target population for the Washington, D. C. campaign (for the comparable 4 to 20 pCi/l category) was only .07%. Results also showed that realtors and employers had played a significant role in helping people get through the testing process. Although mitigation rate estimates for the general population and a subset of that population are not strictly comparable, these results at least

suggest that the time-of-home-sale strategy might prove quite successful in the long term as homes are bought and sold or refinanced.

2.5. A Model of Radon Mitigation

2.5.1. Mitigation Dependent Variable

Given the very low ultimate mitigation rates we have described for the Washington, D. C. radon campaign, it is of prime importance for the development of future risk communication programs for radon to identify what factors those who do mitigate have in common. Using various experiential, psychological, and sociodemographic variables derived from the survey as predictors, we therefore present below a model which predicts whether or not a person who tested and responded to our survey subsequently mitigated.

However, as described in Section 2.4.1, there are several possible ways of defining whether a given household has mitigated or not. We therefore tested three separate models, corresponding to the "claimed," "credible," and "confirmed" categories of mitigation we described above, in an hierarchical fashion. That is, our first model predicts, for all 714 respondents, who among them claimed to take some mitigating action or actions and who did not. Our second model predicts, for only those 192 respondents who claimed mitigation, who mitigated in a credible fashion and who did not. And, our third model predicts, for only those 136 respondents who mitigated credibly, who confirmed mitigation success with a retest and who did not. It should

be noted that, although the ultimate mitigation rates projected for the target population of the campaign were quite low, the proportion of people in our sample who mitigated was quite high since we oversampled the higher radon level categories (see Section 2.3.1). The mitigation rates in our sample were 27% claiming mitigation, 19% mitigating credibly, and 7.4% confirming mitigation.

Since our dependent variable is categorical, there are potential problems with the error structure using an ordinary least squares (OLS) analysis. We therefore performed both OLS and logit analyses for all three models. However, since the results as to which predictors were important were identical from the two analyses (e.g., see Table 2.4) and OLS parameters are easier to interpret, we will focus on the results of the OLS analysis in our discussion.

2.5.2. Potential Predictors of Mitigation

We had several variables available from our survey which were candidates for predictors of mitigation, and we included fourteen of them in the model of claimed mitigation and added one other in the models of credible and confirmed mitigation. These predictor variables are described below in the following conceptual groups: objective risk, subjective perception of risk, characteristics of the individual, characteristics of the home, individual's behavior for other risks, and experience with the risk.

Of course, the objective risk, the radon level measured by a household's Air Chek test, is expected to be an important predictor of mitigation. In our model we used the maximum radon level for the

household reported by either the respondent (for any test results they received) or by Air Chek (for the test kit selected in the sample), as we did for the mitigation pathway analysis in Section 2.4.2.1.[12] Also, since radon readings varied over three orders of magnitude, we used the logarithm of this maximum radon level in our model to correct for positive skewness (Judd and McClelland, 1989).

A common finding in the risk perception literature is that people's actions are often based more on what they perceive the level of risk to be than on the true level of objective risk. Two radon studies, Johnson and Luken (1987) and Weinstein, Sandman, and Roberts (1988), in fact found "perceived seriousness of the risk" to be a significant predictor of mitigation. In our study we did not attempt to obtain a pre-mitigation measure of subjective risk since we did not contact our respondents until after their mitigation decision had been made. However, we did ask them to state their degree of confidence in the accuracy of their test result. We included their responses to this question in the model, although it certainly represents only one of many components that people likely use in developing subjective risk estimates.

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[12] There are potential problems with accepting self-reports of radon test results in determining the maximum radon level, since people may be subject to reporting errors, especially given the typical nine-month lag between receiving the test result and responding to the survey. However, as shown in Section 2.6, if people do err they tend to underestimate, not overestimate, the true test result. And, in any case, we would expect their actions to be based on what they thought the true radon reading was, if this in fact differed from the true reading. Also, the substantive conclusions of the model are the same whether the Air Chek level or the self-reported level or the maximum is used as the dependent measure.

Mitigation choices may vary as a function of several sociodemographic characteristics of the individual. For example, older respondents may be less likely to mitigate because their risk is much more heavily determined by their prior rather than future exposure to radon. Or, people with higher incomes might be more likely to mitigate simply because they are in a better position to pay the expenses incurred by mitigation. Although we do not have specific hypotheses about the effects of these variables on mitigation, we examine gender, age, number of children, education, and income as predictors in our model.

It is also possible that characteristics of the home, not just of the individual, may have an effect on mitigation behavior. We therefore included a categorical variable indicating type of home (single-family detached versus any other type) and the value of the home as predictors in the model. Because home values are unrestricted on the upper end of the scale, reaching into the millions of dollars, we used the logarithm of the reported market value of the home in the model to correct for positive skewness.

There may also be general personality factors in people's risk responses that play a part in radon mitigation: some people may simply be more risk averse than others for many different kinds of risks. We therefore included two behavioral measures of responses to other risks in our model which we thought might represent proxy variables for risk aversion: whether or not the respondent generally wears a seat belt and whether or not the respondent smokes.

Experience with the risk may have an important influence on the decision to mitigate. As a crude measure of benign experience

with radon, we included in the model the number of years the respondent had lived in the residence which they tested. People may also draw upon experience gained through others in responding to radon risk. We therefore included two composite variables in the model to try to capture respondent's exposure to radon information and advice. The "media influence" variable represents whether and how often people saw, for example, TV news shows or public service announcements about radon, radon brochures in public places, radon information in utility bill inserts, and community presentations on radon. The "social influence" variable represents whether and how often people discussed radon with family members, neighbors, real estate agents, and others.

For the credible and confirmed mitigation models we included another predictor, namely, who performed the radon reduction measures on the home. We expect that those who claim to mitigate might be more likely to do so credibly and to retest afterward if they hire a professional to perform the work rather than doing it themselves. This variable was coded -1 if mitigation was conducted by the respondent and +1 if conducted by a private contractor.

2.5.3. Results

2.5.3.1. Claimed Mitigation Model

Table 2.4 gives the partial regression coefficients, their associated t statistics, and PRE (the proportional reduction in error achieved by adding that predictor variable last, also known as the

Table 2.4. OLS Model of Radon Mitigation[a]

Variable	Mean	Std. Dev.	b_j	t	PRE
Dependent Variable					
Claimed mitigation (1 = yes, -1 = no)	-.45	.89			
Predictor Variables					
Constant			-2.245	-2.37	---
Log maximum radon level	2.51	1.48	.235 (.406)	9.35**** (7.96)	.139 (.094)
Confidence in test accuracy (1-7 scale)	4.62	1.60	.073 (.102)	3.44*** (2.80)	.021 (.009)
Gender (1 = female, -1 = male)	-.32	.95	-.099 (-.195)	-2.72** (-2.90)	.013 (.01)
Age (years)	46.12	12.99	-.004 (-.005)	-1.03 (-.75)	.002 (---)
Number of children living at home	.69	1.01	.013 (.012)	.35 (.20)	.0002 (---)
Education (1-10 scale)	7.91	1.72	.015 (.026)	.67 (.66)	.0008 (---)
Income (1-11 scale)	6.32	2.37	-.012 (-.014)	-.72 (-.47)	.001 (---)
Type of home (1 = single fam., -1 = other)	.82	.57	-.015 (.063)	-.24 (.44)	.0001 (---)
Log home value	12.06	.47	.067 (.177)	.79 (1.21)	.001 (---)
Respondent is smoker (1 = no, -1 = yes)	.74	.67	.022 (.028)	.43 (.30)	.0003 (---)
Respondent wears seatbelt (1 = no, -1 = yes)	-.85	.53	.0006 (-.034)	.009 (-.26)	--- (---)
Years lived in home	9.60	8.68	-.001 (-.004)	-.21 (-.46)	--- (---)
Media influence (1-16 scale)	5.28	3.51	-.034 (-.046)	-2.31* (-1.79)	.01 (.002)
Personal influence (1-12 scale)	2.51	2.00	.113 (.167)	5.10**** (4.45)	.046 (.027)
Sample size					556
R^2					.27

[a] Logit results appear below the OLS results in parentheses.
*p < .05 **p < .01 ***p < .001 ****p < .0001

coefficient of partial determination; see Judd and McClelland (1989)) for both the OLS and logit[13] analyses of claimed mitigation.[14] In interpreting these values it should be remembered that the statistical tests are for partial regression coefficients. That is, the test asks whether the given variable reliably explains a portion of the variation in mitigation behavior after controlling for all the other variables included in the model. With covariation among the predictor variables this can produce conservative conclusions about the importance of a variable. Note that approximately 27% of the variation in the coded claimed mitigation variable is accounted for by the model. This is substantial for a model of this type, especially given that the dependent variable is binary.

As expected, log maximum radon level is a highly significant predictor of mitigation ($t = 9.35$, $p < .0001$). This is consistent with the findings of Åckerman (1988). Moreover, the effect is comparatively large, reducing 13.9% of the variance even after controlling for all the other predictors in the model. For a variable that predicts actual behavior on a binary dimension several months in the future, this is an impressive result. The strength of the linear

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[13] The logit results were obtained using the LOGIST procedure in SAS (see "SUGI Supplemental Library User's Guide," Version 5 edition, 1986, SAS Institute, Inc., Cary, North Carolina, pp. 269-294).

[14] The number of respondents represented in this model is 556, not the total sample of 714, because 158 respondents were deleted due to missing data on one or more of the 14 independent variables. Deleting the three variables with the highest number of missing values (income, home value, and education) resulted in 87 more respondents being included in the model, but this did not change the substantive conclusions concerning any of the predictors. We therefore feel justified in presenting the full model with 14 predictors.

relationship between mitigation and log radon level in this study suggests that the failure of Johnson and Luken (1987) to find such a result in their study was simply due to their lack of opportunity to oversample high radon levels.

Our result is harder to reconcile, however, with the conclusions of Weinstein, Klotz, and Sandman (1989). In their study of New Jersey homeowners, they reported a significant but modest-sized linear relationship between "future remediation plans" and radon level. However, when they dichotomized the radon level variable into a crude measure of whether or not the test result was above or below the EPA action level of 4 pCi/l, they found the correlation between mitigation and radon level to increase substantially. They concluded that there was a modest relationship between objective risk and remediation plans, but that this correlation was "entirely due to the distinction of being above or below the guidance level of 4 pCi/l." We regard this result as puzzling, since dichotomizing a continuous predictor usually produces a loss in statistical power if the standard distributional asssumption of normality holds true. We retested our full model of claimed mitigation replacing log radon level with the same dichotomized predictor used by Weinstein, Klotz, and Sandman, and found the dichotomized predictor to still be highly significant but to be less significant than the continuous predictor and to explain a much lower proportion of the variance ($t = 4.9$, $p < .0001$, PRE = .042). Because Weinstein, Klotz, and Sandman removed people who had already mitigated from their analysis of "future remediation plans," they likely had an abnormally large proportion of people in their remaining sample with very high radon levels who did not intend to

mitigate. These "outliers" may have weakened their ability to detect a stronger linear relationship between mitigation and radon level in their data. In short, we believe we have clear evidence from our sample that the proportion of those mitigating systematically increases as radon level increases above 4 pCi/l.

We turn now to a consideration of which predictors of mitigation explain variation over and above the contribution of the objective risk level. Confidence in the accuracy of radon tests was a reliable predictor, with those having more confidence being more likely to mitigate. This verifies the contribution of subjective interpretations of risk in predicting behavior and also suggests that some people may be using lack of confidence in the accuracy of radon tests as an excuse to drop out of the mitigation process.

Among the sociodemographic variables, age, number of children living at home, education, and income had inconsequential effects in our model. This, however, illustrates an interesting point, since models which predict perceived risk from radon typically find, for example, that perceived risk decreases with age and increases for households with children (Sjöberg, 1989). Clearly mitigation behavior displays a different pattern of important predictors than perceived risk.

Gender, however, was a significant predictor in our model, with women being less likely to mitigate than men. This result is in direct contrast with both previous surveys on radon (Sjöberg, 1989) and on other risks such as nuclear energy (Kasperson, Berk, Pijawka, Sharaf, and Wood, 1980) and industrial hazards (Stallen and Tomas, 1988), which have found women to be more concerned than men about risk.

However, since our model predicts mitigation behavior and not concern, it is possible that women in our study were still more concerned even though they were less likely to take protective action. In fact, this result may not indicate a gender difference at all, but simply reflect the fact that many women have less money to spend on radon mitigation than men or have less experience doing the kinds of household repairs that radon mitigation requires. In any case, although gender was a reliable predictor in our model, it's impact was relatively small (PRE = .013).

Type of house and log of home value were not significant predictors in our model, although there may not have been sufficient variation in house type in our sample to test its effect adequately. The two variables measuring behavior for other risks (wearing seatbelts and smoking) were also nonsignificant, although again there may not have been sufficient variation on these dimensions in our sample. In their study of Maine households, which essentially oversampled smokers, Johnson and Luken (1987) found smokers to be significantly less likely to mitigate.

Years lived in home was not a significant predictor of mitigation in our study, although it was in Johnson and Luken's study (those who had been in their homes longer were less likely to mitigate). The composite media influence variable was significant, with people having more media contact about radon being less likely to mitigate. Also, the composite personal influence variable was significant, with people having more discussions concerning radon with others being more likely to mitigate. Of course, these latter two variables are difficult to interpret due to the causal ambiguity inherent in a cross-sectional

survey of this type. For example, the counterintuitive result for media influence might be explained by postulating that people who have mitigated no longer need to attend to or seek out radon information from media sources or that people who mitigate for some reason are also people who spend less time watching television. And, the process of mitigating is just as likely to promote discussions with others about radon as such discussions are to promote mitigation.

2.5.3.2. Credible Mitigation Model

The credible mitigation model predicts, for those who claimed to mitigate, who among them mitigated credibly (reported spending money and could identify the specific reduction method used) and who did not. The modeling procedure was identical to that described for the claimed mitigation model. Only 152 of the 192 respondents who claimed mitigation were included in the model due to missing data on one or more of the 15 predictors. The full model accounted for 13.7% of the variance in the coded credible mitigation variable.

Log radon level was not significant in this model ($\underline{t}$ = 1.14, $\underline{p}$ = .26, n. s., PRE = .01), and in fact only two of the 15 predictors were significant. The gender difference found in the claimed mitigation model was also significant in this model in the same direction ($\underline{b}_j$ = -.23, $\underline{t}$ = -2.5, $\underline{p} < .05$) but was again a relatively small effect (PRE = .04). In our study women were less likely to claim mitigation, and, if they did claim to mitigate, were less likely to do so credibly. Smokers were also less likely to mitigate credibly in this model ($\underline{b}_j$ = .29, $\underline{t}$ = 2.07, $\underline{p} < .05$). In our study smokers, although not significantly less

likely to claim mitigation, were less likely to mitigate credibly, given that they had claimed to mitigate.

Surprisingly, those who hired a private contractor to do the mitigation work were not reliably more likely to have mitigated credibly in this model (t = -0.44, p = .66, n. s.). However, our definition of credible mitigation was quite liberal and included all those who reported spending any money on mitigation, even as little as $5 or $10. It is possible that those who mitigated by themselves tended to choose low-cost, uncertain mitigation methods such as painting and sealing, whereas those who employed a contractor tended to choose higher-cost, more reliable mitigation methods such as forced ventilation, pressurization, or soil suction. To investigate this idea we retested our credible mitigation model using a stricter definition of credible mitigation: in this revised model only those who reported spending more than $50 were considered to have mitigated credibly. Given this revision those who hired a contractor were significantly more likely to have mitigated credibly than those who did not (b_j = 0.28, t = 2.7, p < .01, PRE = .052). Although this argument is somewhat circular, it illustrates an important point: people either hire a contractor and spend a lot of money on a reliable reduction method or they do not hire a contractor and spend very little money on a less reliable reduction method. People generally do not implement the most effective mitigation techniques on their own.

2.5.3.3. Confirmed Mitigation Model

The confirmed mitigation model predicts, for those who mitigated credibly, who among them retested to confirm mitigation success and who did not. The modeling procedure was identical to those described above. Only 111 of the 136 respondents who mitigated credibly were included in the model due to missing data on one or more of the 15 predictors. The full model accounted for 42% of the variance in the coded confirmed mitigation variable.

Log radon level was not significant in this model ($t = 1.67$, $p = .098$, n. s.), although it did account for 3% of the variance after controlling for the other predictors. In fact, only a single predictor in this model, who performed the mitigation work, was significant at the .05 level. Those who hired a private contractor were more likely to retest after mitigation than those who did not ($b_j = .45$, $t = 4.27$, $p < .0001$). This was a strong effect, reducing the variance by 15% even after controlling for the effects of the other predictors. Evidently people simply do not generally retest after they have mitigated unless the mitigation was performed by a professional contractor. This indicates a failure of EPA's message about retesting.

2.5.4. Conclusions

Clearly radon level was the most important predictor of claimed mitigation in our model, and the chance that a household will mitigate increases systematically as radon level increases above 4 pCi/l. The strength of this relationship between mitigation and radon level also suggests that low mitigation rates cannot be explained simply by

postulating that people's protective responses to radon are insensitive to the level of objective risk. However, radon level did not predict who among those who initially did something to mitigate would do so most effectively and completely.

Who performed the mitigation work was clearly the most important predictor of who would mitigate credibly and who would confirm mitigation with a retest, for those who had claimed to mitigate. People who mitigated by themselves were more likely to choose low-cost, less-effective mitigation methods and were less likely to retest after mitigating than those who employed a professional contractor. Apparently very few people make it all the way through the mitigation pathway without help.

After controlling for the effects of radon level, belief in test accuracy, and who did the mitigation work, none of the other predictor categories, including characteristics of individuals, characteristics of homes, proxies for general risky behavior, and experience with the risk, were able to account for a substantial portion of the variation in mitigation behavior (although certain specific predictors such as gender and smoking sometimes had reliable, though small, effects). This was especially true for the final two stages in the mitigation pathway. One is left with the impression that protecting oneself from radon is simply a very difficult task.

2.6. Accuracy in Self-reports of Radon Level

Thus far we have characterized the radon mitigation process as a long and diffficult one. We have also been able to document several

major steps along the pathway to successful mitigation at which people drop out: failure to return a test kit once it has been purchased, failure to choose effective mitigation methods, and failure to retest after mitigating. However, each of these stages likely encompasses many (perhaps dozens of) smaller stages which our survey was unable to document. For example, simply "returning a test kit for evaluation" involves following instructions to set up the test correctly, getting the proper exposure, resealing the container properly several days later, mailing the test back to Air Chek, and attending to and interpreting the results. "Mitigation" might involve seeking information from several sources by phone or mail, asking many different people for advice, going through the entire testing process all over again once or twice, doing some banking and accounting, and making several trips to the hardware store.

One of these "microstages" we do have information on is people's ability to remember their radon level correctly. If people do not remember or if they misremember their radon level, they might drop out of the mitigation process because they mistakenly think their level is safe, or may perhaps mitigate unnecessarily if they mistakenly think their radon level is high. To investigate this question we tested whether the difference between people's self-reports of their initial radon level and the radon level reported to them by the testing company was significantly different from zero. Because we only had access to one test kit reading from Air Chek for each respondent, and many respondents reported using more than one test kit, we included in the model only those 499 respondents who reported using one test

kit. Of these 499 respondents, 125 (25.5%) were unable to state their radon test results in picocuries per liter on the survey.

For those 374 respondents who did report a radon level, the mean difference score was significantly less than zero (mean = -2.39 pCi/l, t = -3.5, $p < .001$, PRE = .03), indicating a reliable tendency for self-reports to underrepresent true radon readings. However, this simple interpretation is misleading, which can be seen from the pattern of the errors associated with the model. Figure 2.4 displays a plot of self-reporting error versus Air Chek radon level for the 374 respondents in the model. Clearly, the typical person did not underreport his or her radon level by 2.39 pCi/l. Instead, many people knew their radon level exactly, or nearly so. However, if they did make an error, it was likely to be an underreporting error, and the pattern of errors is markedly heteroskedastic. That is, the size of the errors increases as the true radon level increases.

Of course, we don't know if remembering an incorrect radon level makes people less likely to mitigate or if those who do not mitigate are less likely to remember their radon level correctly. However, this analysis at least raises the possibility that some people may not be mitigating simply because they misremember their radon level. In fact, of the 21 respondents in our survey who underrepresented their true radon reading by 25 pCi/l or more, not a single one mitigated credibly. This is a good illustration of how an error at one small, simple stage along the mitigation pathway can lead people to drop out of the process.

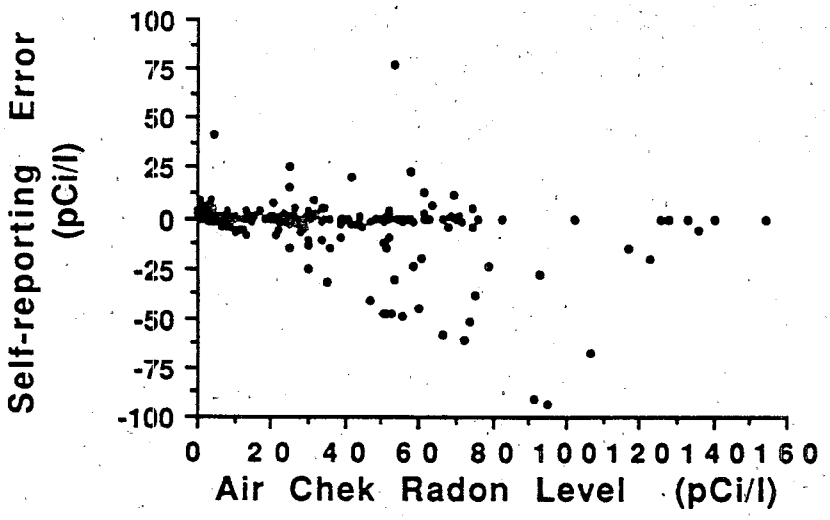

Fig. 2.4. Self-reporting error versus Air Chek radon level for respondents who reported using one test kit and who reported their radon level in picocuries per liter.

2.7. Conclusion

We have presented several kinds of evidence that radon is a particularly intractable risk in the sense of being difficult to manage and manipulate and being resistant to well-meaning efforts at reduction. A radon testing and information campaign aimed at the general public was shown to result in very low ultimate mitigation rates. Many of those who claimed to mitigate did not do so in an effective way. Those who received professional help during the mitigation process, however, were much more likely to mitigate credibly and to confirm that their mitigation efforts had succeeded. Only just over half of those who purchased radon test kits even returned them for analysis, and many of those who did test could not recall their radon reading or recalled it incorrectly.

Although characteristics of radon risk such as benign experience and lack of perceptual cues (see Chapter 1) likely play a significant role, the major determinants of low mitigation rates appear to be instead characteristics of the protective responses required to reduce the risk from radon, which in general are complicated and difficult. It has been suggested that people would be more concerned about radon if it had an identifiable odor such as that which is added to natural gas. Similarly, many more people would likely act to reduce radon levels if mitigation were as simple as putting on a seatbelt.

It is also interesting to consider two home risks with solutions that have very high adoption rates. These are crime and fire. It has been estimated that about 40% of households have purchased security devices such as bars, special locks, and burglar alarms to prevent crime (Dubow, McCabe, and Kaplan, 1979) and about 60% of households (in areas where they are not required by law) have installed smoke detectors (Jensen, Tome, and Darby, 1989). Admittedly, these risks are very different from radon in some ways, for example, they are often highlighted on the evening news, they are dramatic and perhaps "dread" risks, and many people might receive economic incentives (lower insurance premiums) to take protective action. Still, it is likely that one contributing factor to these high adoption rates is that the protective behaviors required are relatively simple, known, one-time behaviors. In the case of fire, for example, you need only buy a smoke detector from the hardware store, install it like you did your ceiling lights, and put in batteries like you did for your tape recorder. Although this task may be more difficult for some people than for others, years of protection can be gained from a single

afternoon's effort. In contrast, there is simply no way to reliably reduce one's risk from radon that takes less than several weeks.

Protecting oneself from radon is a long, difficult, multistage, multifaceted, technical, multiperson, multiskill, recursive process. The following list details several characteristics of the protective reponse to radon which we feel govern radon mitigation behavior just as the risk characteristics we presented in Chapter 1 appear to govern radon risk perception:

1. Mitigation takes a long time, often several months or longer, to complete.

2. Mitigation is a multistage process, with successful completion of one stage necessary for completion of subsequent stages; people may drop out partway through the process at any of several points.

3. Parts of the process, especially testing, are very technical, unfamiliar, and not easily understood.

4. Except for extreme radon levels, there is little time pressure to complete the mitigation process.

5. Radon mitigation is a multiperson activity, requiring contact and often coordination with testing company employees and contractors and perhaps seeking information from neighbors, government employees, employers, or realtors.

6. Radon mitigation requires a wide variety of skills and qualities (for example, interpersonal skills, patience, persistence, home repair skills, ability to interpret technical information) which may not often occur together in a single household.

7. All of the effort and expense for a lifetime of protection occurs up front.

8. The testing process is recursive, requiring the same procedures to be performed as many as three or four different times.

It is no surprise that many people do not make it all the way through the mitigation pathway when the necessary protective responses are characterized in this way.

Other risks which share many of these protective response characteristics may also prove to be extremely difficult for people to deal with and protect themselves from without help. Such a list of intractable risks might include, for example, asbestos fibers from building materials, lead in drinking water, contamination of wells by toxic chemicals in groundwater, vapors from urea-formaldehyde foam used for insulation, and a host of other indoor air pollutants. Traditional information and awareness campaigns are unlikely to be an effective public policy for such risks. They may instead require regulation or the recruitment of professionals who can provide people with active guidance and personal assistance.

Chapter 3

An Evaluation of Radon Testing and Mitigation at Time of Home Sale

3.1. Introduction

Given the low overall effectiveness of an information and awareness program targeted at the general population, as shown in the previous chapter, this chapter presents a study which explores the potential effectiveness of targeting radon information and/or regulation at the point of home sale. Since single family homes are sold about every ten years on the average, this approach cannot yield an immediate solution to the radon problem. However, if individual or institutional behavior in the setting of the home sale frequently leads to testing and mitigation, this approach might provide an effective long run solution.

Thus, the purpose of the study reported in this chapter is to conduct a telephone survey of recent home buyers in Boulder County, Colorado to determine if testing at the time of home sale has become common practice and if such testing leads to mitigation. It should be noted that no extensive information and awareness campaign has been conducted in the State of Colorado, so any testing that occurs is motivated by generally available radon information. For example, news stories indicating that Colorado has the highest percentage of homes

across the nation violating the EPA guideline for radon have appeared in both newspapers and on television. If substantial mitigation is already occurring in Boulder County, and we can determine the underlying causes, that result would suggest that the point of home sale is an effective time to attempt to encourage further testing and mitigation in other areas.

The research presented here is based on a sample of 303 homes for which telephone interviews were completed. Because the frequencies of testing and mitigation by home buyers and sellers were unknown, it was our view that it would be unwise to expend a large amount of money sampling for what might be low frequency events (i.e., testing and mitigation). For example, had we sampled the general population rather than people who had tested for radon in the study reported in the previous chapter, less than 10% of the sample would have been of interest (i.e., purchased test kits and possibly mitigated as a result of the program). Fortunately, in our study we found that 44.6% of a sample of recent home buyers in Boulder County had obtained radon test results prior to closing on their new home. Home sales in and of themselves appear to motivate testing.

The rest of the chapter is organized as follows. Section 3.2 describes the design of the telephone survey, while Section 3.3 presents the sampling plan. Sections 3.4 and 3.5 give descriptive results and present our data analysis, respectively, while Section 3.6 contains our conclusions and recommendations.

3.2. Survey Design

The survey instrument used in this field study is reproduced in Appendix II, along with summary results for each question. Where appropriate, results are provided for both those who tested and those who did not. The survey was designed to be administered over the telephone by interviewers who were not knowledgeable about radon and to take no more than 10 or 15 minutes to complete.

The interviewers were instructed to speak only to the property owner whose name we had obtained or to a co-owner of the property. Respondents were then screened to confirm that they had recently purchased property in Boulder County and that this property was their primary place of residence. Respondents were read a short statement that stated that the survey concerned radon gas, that it would take about 15 minutes to complete, and that all responses would be completely confidential. The interviewers were provided with three additional statements to read if the respondent resisted or wanted to know how they were chosen. Respondents with questions about the survey or problems were given the name and telephone number of one of the investigators.

All respondents were asked 23 questions, and 34 additional questions were asked of some respondents to collect more detailed information concerning those whose homes had been tested for radon. The questions were selected to provide information on three interrelated areas:

1. What percentage of recently sold homes are tested for radon and what percentage of these homes make it through the entire mitigation process (especially in comparison to the corresponding percentages obtained in the information and testing campaign detailed in Chapter 2)?

2. What is the story behind why radon tests at time of home sale occur and how does radon affect the sale negotiation process?

3. What differences are there between people whose homes are tested and people whose homes are not tested at time of sale?

The survey questions were organized into six sections. The first section was a general introductory section designed to gather some information on respondents' experience with radon prior to finding their new home. The second section was designed to determine if and when a radon test occurred and to ask detailed questions about how and why the test was done for those whose homes were tested. (Since pretesting led us to expect that people might have difficulty reporting the results of the radon test in picocuries per liter, respondents were prompted with the phrase "remember that the EPA action level is 4 picocuries per liter" and were asked to rate the test result on a 5-point scale ranging from "very low" to "very high" if they could not report the exact result.) The third section asks if and when any attempt was made to reduce the radon level and also asks detailed questions about how and why the reduction effort was conducted for those homes that underwent mitigation. The fourth section asks specific questions concerning how radon enters into and affects the sales transaction for those whose homes were tested and documents the types of clauses concerning radon that are presently being added to sales contracts in Boulder County. The fifth section asks general

questions concerning transactions and the negotiating process in order to assess what effect, if any, radon may have on other, more general, aspects of the sales process such as length of time to reach an agreement and final negotiated sales price. Also, one aspect of the transaction process, whether a realtor was employed and, if so, what advice the realtor gave the buyer about radon, was assessed to determine how it might affect the likelihood of a test being conducted. The final section covers the standard demographic information as well as some additional demographic information of special relevance for radon. A few questions are designed to determine whether the respondent has a general tendency to engage in risky behaviors such as not wearing a seat belt when driving. Also, respondents are asked whether they work for IBM because of IBM's radon program, which requires testing and mitigation to below 4 pCi/l for employees in order for them to participate in the company's housing buyback program in the event they are transferred away from Boulder. IBM employees are therefore in a very different situation than non-IBM employees with respect to the options open to them concerning radon, and may need to be analyzed separately.

In addition, the fact that many real estate agents in the Boulder County area are knowledgeable about radon may be partially due to their having to deal with IBM employees as customers. The presence of such a major company with a very strict radon policy may therefore be influencing radon testing and mitigation behavior in Boulder County even for non-IBM employees. Testing and mitigation rates at time of home sale in Boulder County might be somewhat elevated in comparison to communities in which no major employer with a radon

policy exists. However, these rates are surely lower than for many communities in Pennsylvania and New Jersey in which realtors have been involved with radon for several years and in which realtor associations have adopted radon policies. And, in any case, the rates in Boulder County, which have been motivated by private market interests, are surely minimum estimates of what could be achieved with a government-sponsored risk communication strategy at time of home sale.

3.3. Sample Design

The sampling plan was based on inclusive lists of individuals who had recently bought homes in Boulder County. (It should be noted that we attempted to contact all of the homes recently bought in Boulder County during a specific period of time, and therefore our sample included the entire population of interest, not a smaller randomly chosen subset of that population.) The lists of names were taken from a local newspaper which publishes all Boulder County property sales on a weekly basis and provides the property buyer's name and the address of the purchased property. Buyers of commercial property and apartment buildings were deleted from the lists. Directory assistance was used to obtain phone numbers for each person on the lists. Overall one-third of the names were deleted from the lists because they had bought commercial property rather than residential, they did not yet have a phone number, they had an unlisted phone number, they were not qualified to participate in the survey, or their phone numbers turned out to be wrong or disconnected.

An initial administration of the survey took place in December of 1988. The goal of this first administration was to obtain a pilot sample to determine if collection of a larger sample would be useful. A list of 195 people with good telephone numbers who had purchased homes from September to November of 1988 was prepared as outlined above, and 100 of these 195 calls were successfully completed. [15]

A second administration of the identical survey was conducted in February of 1990 to increase the sample size and response rate of the initial pilot survey. [16] All of the 95 people who did not complete the survey in its initial administration were tried again, and 51 of these 95 people completed the survey at this time. In addition, a list of 301 new names of people with good telephone numbers who had purchased homes between December of 1988 and early February of 1989 was prepared, and 153 of these people completed the survey.

Data from both of these administrations is combined in the results and analyses to be presented below. Overall, 303 surveys were completed from lists containing 496 new home buyers for which good

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[15] In this initial sample an attempt was made to oversample areas of Boulder County in which we expected to find more IBM employees, since we wanted to ensure adequate numbers of IBM employees in the sample to investigate the impact of IBM's radon policy. However, the percentage of IBM employees did not vary between the area which was oversampled and the other areas of Boulder County (10% versus 13%, respectively). We therefore did not analyze data from these areas separately and also did not oversample any areas in the second administration of the survey.

[16] The only changes made to the survey were (1) changing the phrase "new home" to "present home" because over a year had passed since the first administration and (2) including a new screening question which identified people who had moved again since the winter of 1988-1989.

telephone numbers could be located, yielding an overall response rate of 61.1%. We have no theoretical reason to expect that those we were unable to locate a telephone number for should differ from respondents in any way. We did, however, expect that those who refused to answer the survey when contacted might differ significantly from respondents, perhaps having a lower testing rate. We therefore asked these people a single simple question, Was your present home tested for radon before the sale closed? Of the 80 people who were contacted and refused to complete the survey, 66 did answer this one question. The testing rate before closing for this group of refusals was 27.2%, significantly lower than the rate for respondents. We assess the impact of this lower testing rate for nonrespondents in Section 3.5.

Since the sampling plan described above resulted in three distinct samples (homes in the initial sample contacted in December of 1988, homes in the initial sample contacted in February of 1990, and homes in the second sample contacted in February of 1990), we compared these samples on several key variables to determine if there were any major differences. There was little difference between the three samples on whether or not they employed a realtor (for all three samples between 77 and 83% employed a realtor) but there was some difference in the percentage of testers with test results greater than 4 pCi/l or "above average" (between 16 and 29% for all three samples). The testing rate before closing for the second sample (50.7%) was higher than for the original sample (39%), indicating that testing rates at time of home sale may be increasing over time. In addition, the testing rate after closing for people in the original sample who were

contacted in February of 1989 (19.6%) was higher than that for people in the original sample who were contacted in December of 1988, which likely reflects the fact that those in the former sample simply had another year in which to conduct tests.

3.4. Descriptive Results

A facsimile survey is presented in Appendix II which includes the number of responses and the overall descriptive results, either means or frequencies as appropriate, for each survey question. When the comparison is useful, separate results are also reported for those respondents whose homes were tested (either before or after the sale closed) versus those whose homes were not tested. We shall briefly discuss some of the highlights of these results below. Those respondents whose homes were tested will be referred to as "testers" and those whose homes were not tested will be referred to as "nontesters" in the following discussion.

3.4.1. Introductory Questions

Responses indicate that 98% of those surveyed had at least heard of the radon problem. Overall, over half of the respondents first heard about radon more than 1 year ago. Testers were slightly more likely to have first heard about radon more than one year ago and slightly more likely to have first heard about radon before they began their most recent home search, indicating that knowledge about radon prior to buying a home may help people in making appropriate choices concerning radon at time of home purchase. Question 3 documents

the large variance and bimodality in people's attitudes toward radon: one-fifth of the respondents indicated that it was "not at all important" to them to buy a home with a safe radon level, whereas another one-fourth of the respondents indicated that it was "very important." Responses to question 6 indicate that there is little difference in the generl home buying experience of testers versus nontesters, with about 60% of each group having purchased a home once before. Not surprisingly, testers rated the importance of buying a home with a safe radon level higher than nontesters (means 5.3 vs. 3.1) and were much more likely (47.3% vs. 22%) to have had their previous home tested for radon. Evidently those who have experience with radon testing in one real estate transaction do tend to make testing part of their next real estate transaction.

3.4.2. Radon Testing

Overall 154 of 303 respondents (50.8%) indicated that their new home had been tested for radon. Twenty six (8.6%) of these tests took place before the buyer first looked at the home, 109 (36%) of the tests took place before the sale closed (and typically after negotiations had begun), and 19 of the tests (6.3%) took place after the closing. The buyer was the most likely person to have first requested the test (67.5% of the time) and to have paid for the test (51.3% of the time), but many other categories of people, including sellers, realtors, contractors, employers, and bankers are represented in the responses to these questions. The radon test was conducted by a professional (either a realtor, building contractor, or radon testing firm) 48% of

the time. Of the 154 testers, 73 of them were able to state their test results precisely in picocuries per liter, and almost all testers could at least describe the test results in such terms as "low," "about average," or "high." Of the 73 test results stated in picocuries per liter, the mean result was 4.2 pCi/l, the lowest result was 0.2 pCi/l, and the highest result was 18.0 pCi/l. Of the 81 test results not stated in picocuries per liter, 64.2% were described as "low" or "very low," 14.8% were described as "average," and 7.4% were described as "high." In the analysis that follows, both numeric and descriptive test results are combined into a single measure, whether or not the test result was below or above the EPA action guideline of 4 picocuries per liter. Descriptive results were fit into this framework by assuming "very low," "low," and "average" results to be less than or equal to 4 pCi/l and "high" and "very high" results to be greater than 4 pCi/l. Testers seemed to have a relatively high degree of confidence that their test results were accurate, rating their confidence, on average, at 5.5 on a 1 to 7 scale.

3.4.3. Radon Mitigation

Twenty four respondents of the 154 who tested indicated that some attempt at mitigation had been made (answered yes to the question, Was any attempt made to reduce the radon level in your new home before the sale closed?), and 14 of them were able to state exactly how much money had been spent on the mitigation effort. Overall, 16 of the 31 testers with test results greater than 4 pCi/l or a "high" result claimed to mitigate, and for 14 of these 16 the success of

the mitigation effort had been evaluated by a retest. Again, over half of the time the work involving radon was performed by professionals. The maximum post-mitigation test result reported was 5.0 pCi/l and the mean was 2.8 pCi/l, indicating that the mitigation efforts were generally effective.

3.4.4. Radon Transactions and Negotiation

Only 2 of the 154 testers (1.3%) reported that they had negotiated a reduction in the sale price of their new home "specifically because of concern about radon or because of radon test results." One of the major concerns, from a public health perspective, about a risk communication at time of home sale strategy without enforced mitigation is the potential for new homeowners to accept monetary compensation in place of mitigating the radon hazard, which would simply leave sellers poorer and result in no reduction in radon risk for the buyer. Based on our survey results, it appears that people simply do not, or at least only extremely rarely, resolve a radon problem with a seller by accepting a price reduction in place of mitigation before closing.

About 40% of the testers reported that there was a clause concerning radon in the final sales contract for their home. Of these contracts with a radon clause, 90.2% of the time the clause stated that the sale was contingent on a radon test, 52.5% of the time the clause stated that the seller must reduce the radon level if found to be unsatisfactory, and 52.5% of the time the clause stated that the home

must meet a specific radon level (16 contracts used the EPA action level of 4 pCi/l and one used 20 pCi/l).

Another concern about the time of home sale strategy is that sellers, who are often still living in a home during negotiations, might be motivated to leave their windows open more often or in some other way sabotage the radon test results in order to save money or to speed negotiations along. In our survey, however, buyers indicated a high level of confidence that their test results were accurate. In addition, there was little difference in the percentage of homes falling into the >4 pCi/l category depending on whether or not the home was occupied by someone else while the test was being conducted (25.3% versus 18.6%) and this difference was not significant in a simple model which used whether or not the home was occupied during testing to predict radon level category ($t = 0.9$, n.s.). Although our study does not entirely rule out the possibility that some sabotaging of radon tests by owners is going on, it does indicate that the size of such an effect must be rather small.

3.4.5. General Transactions and Negotiation

Overall the mean number of weeks it took to close the home sale was 6.4 and the mean number of offers submitted by the buyers was 1.7. The overall mean sale price of the homes was $118,118. The mean sale price was higher for tested ($127,180) versus nontested ($108,912) homes, indicating a tendency for more expensive homes to be more likely to be tested, but the existence of a radon test result had no measurable effect on aspects of the sales transaction such as

time to close, number of offers and counteroffers, and final negotiated sale price. Any effect radon may be having on these variables is likely overshadowed by other effects--time of home sale therefore appears to be a context in which the trouble and expense associated with radon may be able to be framed as very small.

Overall 79.3% of the buyers employed the services of a realtor, and 43.7% of these realtors gave some kind of information or advice about radon to the buyer. Testers were more likely to have employed a realtor (84.2% vs. 74.1%) and were substantially more likely to have employed a realtor who gave them information on radon (57.5% vs. 26.9%) than nontesters. In general, many realtors in Boulder County are doing a good job of informing clients about radon and of motivating radon testing at time of home sale. They are not, however, effectively promoting radon mitigation. Out of 31 homes in this study which were tested and received a test result greater than 4 pCi/l, 15 did not claim to mitigate. All 15 had employed the services of a realtor. It is possible that realtors may be taking responsibility for testing since it is relatively inexpensive but do not want to take responsibility for promoting mitigation because it is rather expensive, and they do not want to be held liable for imposing costs on a seller without a legal basis for their action. Another possibility is that realtors are simply subject to the same lack of concern over radon levels below 20 pCi/l as other people are, and see no need to ensure that mitigation occurs. Most likely of all, realtors probably do not know exactly what they should be doing about radon mitigation in order to best serve their clients. In any case, it is clear that there is a great need for EPA informational materials directed at realtors which encourage them to

take an active role in promoting testing and seeing that radon mitigation occurs, when appropriate, at the time of home sale.

3.4.6. Characteristics of the Respondents

Overall 63.8% of the respondents were male. The mean age of the respondents was 37.4, and the "typical" household had 1 child, 2 adults, and only very rarely an adult over the age of 65. As a group the respondents were very highly educated, with the median educational level being "completed college." The median household annual income was in the $50,000 to $59,999 range. None of these variables differed substantially between the testing/nontesting groups. Also, overall 11% of the respondents indicated they were smokers and 9% indicated that they did not generally wear a seat belt when traveling by automobile. The percentage of smokers did not vary between testing/nontesting group, but nontesters were slightly more likely to not wear a seat belt than testers. In general, time of home sale appears to be a context in which individual differences in demographic characteristics (e.g., age) and tendencies toward risky behavior (e.g., smoking) that are commonly correlated with attitudes and behaviors toward radon may often be overridden by other factors. The one demographic variable with a marked difference between testing/nontesting group was whether or not the respondent was employed by IBM: 17% of testers but only 6.2% of nontesters stated that they were currently IBM employees. The effect of the high testing and mitigation rates of the subpopulation of IBM employees on our overall analysis are discussed in the next section.

3.5. Data Analysis and Discussion

Throughout this report we have emphasized that the process of protecting oneself from the risk associated with radon gas is a long and difficult one, with many opportunities to drop out at different stages along the way. The effectiveness of a risk communication program or strategy for radon is perhaps best measured by the number of people the program is able to keep involved in the process as the stages progress from initial interest and concern to testing to interpretation of test results to mitigation and finally to confirmatory retesting. In order to interpret the data from this survey (just as we did for the survey data in Chapter 2) we will therefore concentrate on how many people are retained at each of the various stages, given the time-of-home-sale context.

Although it is difficult to compare the overall relative success of the Washington, D. C. information and awareness campaign (which was aimed at the general public) and the Boulder County, Colorado study (which focused on the behavior of a subpopulation of people who had recently purchased homes and which measured preexisting behavior, not responses to a risk communication campaign), we can document the testing rate already occurring in absence of regulation by government at time of home sale and we <u>can</u> directly compare the relative effectiveness of each context in promoting mitigation and confirmatory retesting. That is, given that a test has been conducted, either within the home sale context (Boulder study) or outside of the home sale context (Washington, D. C. study), we can directly compare

the subsequent mitigation and retesting rates. From Chapter 2, the transition rate in the population exposed to the information and testing campaign, for all radon levels greater than 4 pCi/l, from testing through mitigation to credible mitigation to confirmatory retesting was 14.8% X 53.5% X 34.4% = 2.7%. For radon levels between 4 and 20 pCi/l, the transition rate from testing to confirmatory retesting was even lower: 11.9% X 46% X 33.3% = 1.8%. We now turn our attention to presenting the comparable transition rates from the Boulder, Colorado study.

A chart of the pathway to mitigation for all 303 respondents in the Boulder, Colorado study is presented in Fig. 3.1. Only those homes which were tested before closing are included in the testing stage of this chart and the following charts (although 19 homes tested for radon after closing, these tests cannot be unequivocally related to the home sale transaction). Those 26 homes which were tested before the eventual buyer first looked at them <u>are</u> included in the charts, since, although they cannot be related to characteristics of the buyer, they are still a result of the home sale transaction. Overall, 135 out of the 303 original homes were tested for radon before closing. The testing rate of 44.6% for this subpopulation of home buyers is about 12 times higher than that for the general population in the Washington, D. C. study. Twenty-eight of the test results were higher than the EPA action level of 4 pCi/l. Of these 28 homes, 15 (53.6%) claimed mitigation. Although we don't have a measure of "credible" mitigation as we did for the Washington, D. C. study, we do have the same measure of "confirmed mitigation," whether or not a confirmatory retest was performed after the mitigation effort, so we can compute

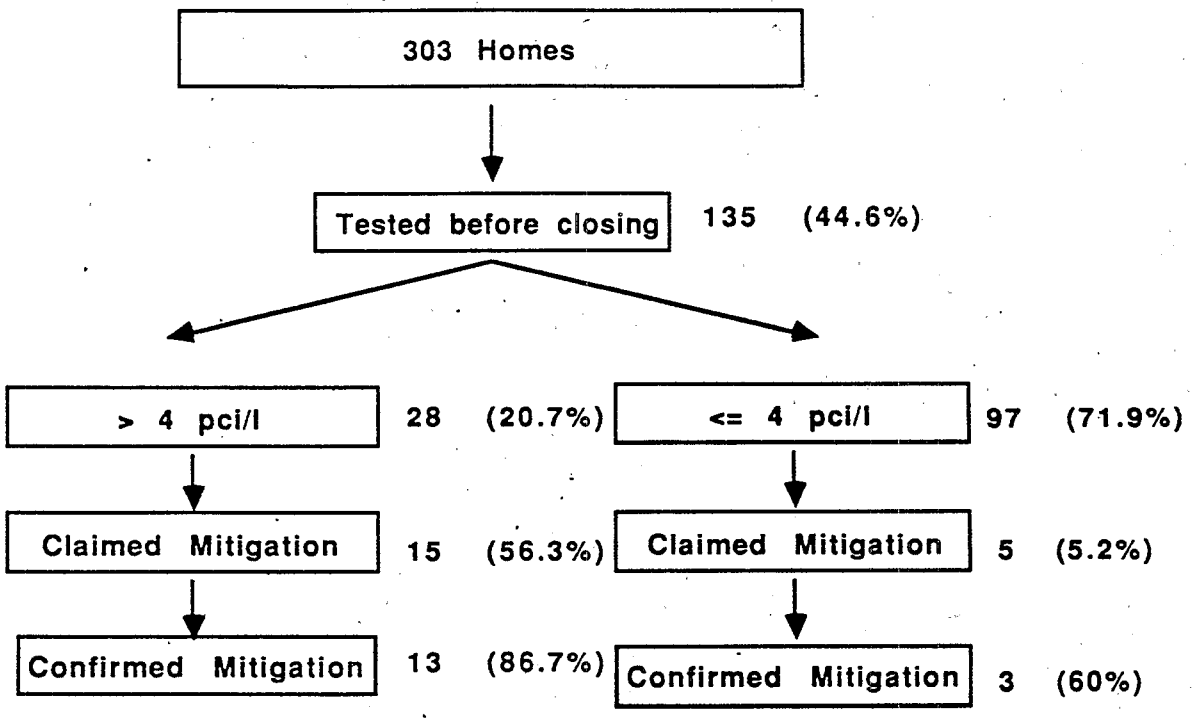

Fig. 3.1. Radon mitigation pathway for all 303 home buyers, by radon level category. (The percentages for partitioning by radon level category do not sum to 100 because 10 respondents could not report or estimate their radon level.)

the same transition rate from testing to confirmed mitigation. Of the 15 homes which claimed mitigation, 13 (86.7%) were retested to confirm that the mitigation effort had been successful. The overall transition rate from testing to confirmed mitigation for the Boulder sample of new home buyers was therefore 53.6% X 86.7% = 46.5%. Compared to the comparable 2.7% transition rate calculated above for the Washington, D. C. study, the 46.5% transition rate is a very impressive result, even if it does apply only to a subpopulation of new home buyers (which typically makes up about 5% of the general population each year). It is more impressive when one considers that

the radon test results from the Boulder study all fell into the 4-20 pCi/l category, since we were unable to oversample high radon levels, and the 46.5% transition rate might therefore be more comparable to the even lower transition rate of 1.8% from the 4-20 pCi/l category in the Washington, D. C. study. These participation rates are very high in comparison with those commonly found in all types of risk communication campaigns directed at the general public: we have clearly succeeded in identifying a subpopulation in which radon testing rates are high and in which people more often remain in the process until protection against the risk posed by radon is assured.

It is possible that these impressive testing and mitigation rates are being driven solely by the behavior of IBM employees, who, as we have described, face a strong economic incentive to test and mitigate for radon. To address this issue we present in Fig. 3.2 a mitigation pathway identical to that in Fig. 3.1, except that all 35 IBM employees have been removed. The testing rate decreases only from 44.6% to 40.7% when all IBM employees are removed. The transition from testing to claimed mitigation for test results greater than 4 pCi/l decreases slightly more, from 53.6% to 40.9%, but remains quite high. The transition from claimed mitigation to confirmed mitigation is identical. It is true that testing and mitigation rates for employees

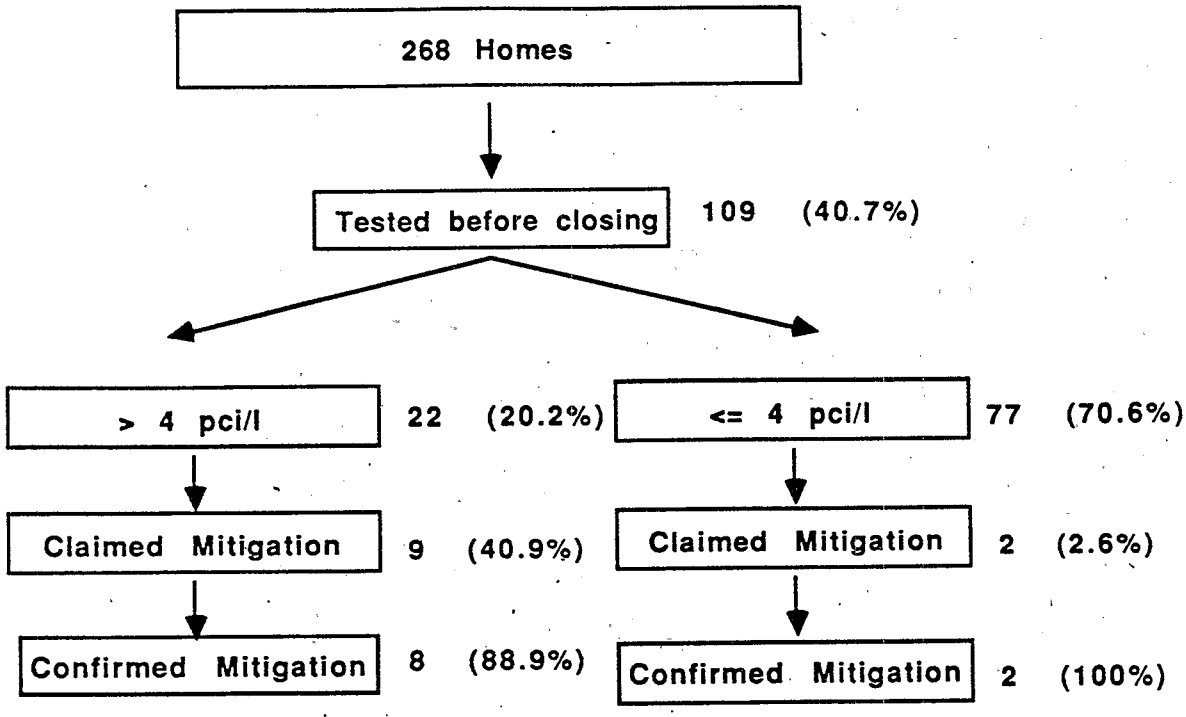

Fig. 3.2. Radon mitigation pathway for all non-IBM home buyers, by radon level category. (The percentages for partitioning by radon level category do not sum to 100 because 10 respondents could not report or estimate their radon level.)

facing a strong economic incentive from their employers to test and mitigate their new homes for radon are uncommonly high -- but the testing and mitigation rates for anyone purchasing a new home are also quite high. However, IBM's radon program may be having an indirect effect on the radon testing behavior of home buyers and sellers in the Boulder County area at large, due to its impact on realtors who must often sell to IBM employees. Realtors in Boulder County may therefore be somewhat more likely to disseminate radon information than those in communities that have no employer with a radon program -- but there are still many realtors in Boulder County

who don't generally inform their clients about radon. The high testing and mitigation rates currently being achieved in Boulder County surely are great underestimates of the potential that could be achieved from a radon disclosure at time of home sale strategy implemented by government.

Another concern to our estimates of testing and mitigation rates for the Boulder study is the possibility that testing rates for nonrespondents could be significantly lower than testing rates for those who completed the survey. To investigate this possibility, during the second administration of the survey in February of 1989, we asked those people who were contacted but refused to participate in the survey to answer one simple question, namely, Was your present home tested for radon before the sale closed? Sixty-six of 80 people answered this question, and the testing rate for these people was 27.2%. Although half of our nonrespondents were not refusals, but simply people we were unable to contact, we will assume that this lower testing rate applies to all 189 nonrespondents. We can then construct a worst-case testing rate for all 492 homes on our survey lists, representing all homes sold in Boulder County from September of 1988 to early February 1989 for which a good telephone number was available. The estimated testing rate for all 492 homes is 37.9%, only 6.7% lower than the testing rate for the 303 respondents and still uncommonly high, even for a subpopulation of the general population. Although we were unable to assess mitigation rates for nonrespondents, we have no reason to expect them to be substantially lower than the rates for respondents.

The obvious disadvantage of the time-of-home-sale approach to promoting radon testing and effective radon mitigation is that it is a long-term solution and would take years to reach a lot of people, as homes are slowly, but inevitably, bought and sold at the rate of about 5% per year. In fact, if one takes the testing rate of 44.6% for respondents to the Boulder, Colorado study and multiplies it by 5%, the result is a testing rate of 2.2% of the general population of Boulder County testing in a given year, roughly equivalent to the testing rate found for the general population which was the target of the Wahington, D. C. information and testing campaign.

However, there are several reasons to expect a time-of-home-sale strategy to be more successful in promoting effective radon mitigation in the long term than an information and awareness strategy. First of all, the testing and mitigation rates achieved by the Washington, D. C. campaign were the result of an intensive, well-organized mass media risk communication campaign. In contrast, the testing and mitigation rates found for the Boulder study have occurred in the absence of any radon risk communication campaign of any sort in the Boulder County area -- surely it represents the bare minimum that could be achieved by a policy which aims risk communication materials at realtors and lenders and promotes or mandates disclosure of radon test results at time of home sale. A second advantage to the time-of-home-sale strategy is that it targets homes rather than people -- even people who are highly resistant to radon testing or show a great lack of concern for the risk may eventually face a situation in which they become protected from radon (perhaps by buying a house that has already been tested and mitigated or by facing an economic

incentive from an employer or lender). Third, there is every reason to expect participation rates for an information and awareness strategy to decrease over the years, since each year the people most likely to paritcipate are recruited, leaving a more resistant population for the next year. In contrast, the rate at which homes are sold remains relatively constant year in and year out, and those who test and mitigate are not different from those who don't. Fourth, there may be a ceiling on the testing rate that can be achieved in the general population. Areas in New Jersey and Pennsylvania which have elevated radon levels and which have been in the news for years and in which there are helpful state programs which promote testing are having trouble achieving testing rates much higher than 40%. The time-of-home-sale strategy would not be subject to such a ceiling effect. Fifth, radon testing and mitigation in the home sale context is more likely to be conducted by professionals, probably because the cost in this context can be framed as small, and is therefore more likely to be complete and effective. Finally, the transition rates after testing are markedly low in the general population (Washington, D. C. study): only 14.8% of those with test results above 4 pCi/l even claim to mitigate, only about half of those who claim to mitigate do so credibly, and only about a third of those who mitigate credibly conduct a confirmatory retest. High transition rates at these stages may simply be unachievable in the general population -- but they are achievable given the assistance provided by professionals and the pressures to resolve a radon problem which occur in the time-of-home-sale context.

We shall now turn to a closer examination of two factors which appear to be related to high testing and mitigation rates in this study:

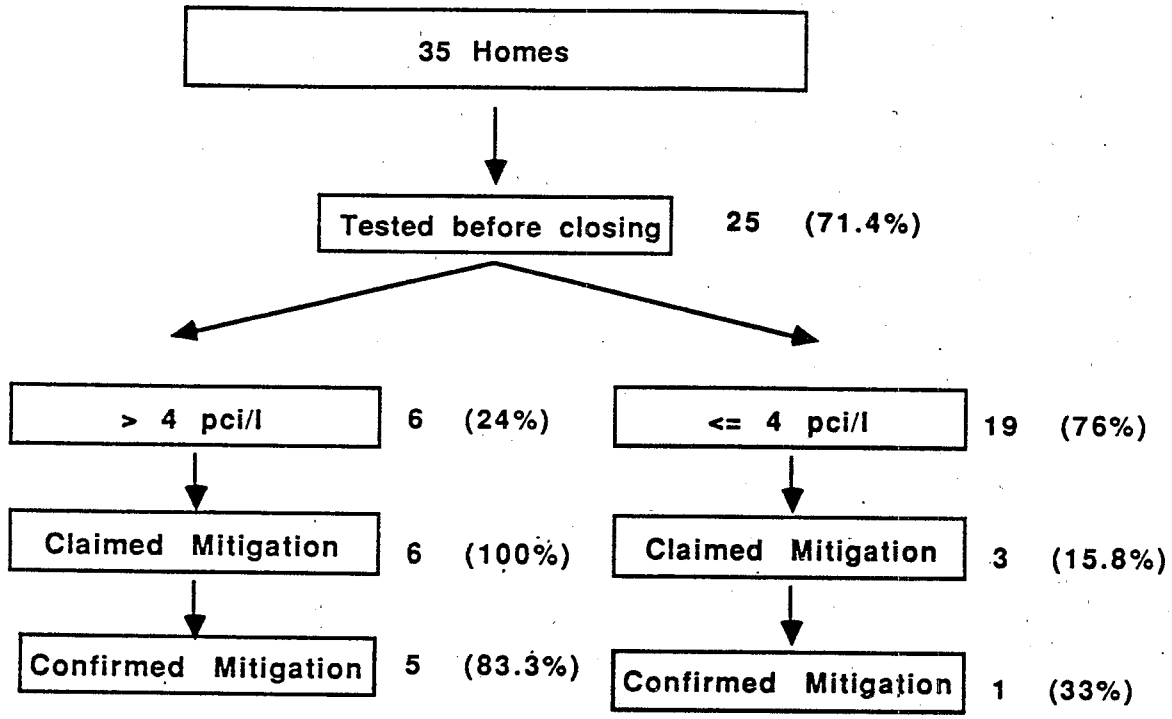

Fig. 3.3. Radon mitigation pathway for 35 IBM employees, by radon level category.

employment by IBM and hiring the services of a realtor who is knowledgeable about radon. In order to gain more insight into these factors we have separated the 303 respondents into three different groups and constructed three separate charts of the pathway to mitigation. Figure 3.3 displays a chart for the 35 respondents who work for IBM. The homes of 25 of the 35 were tested, 6 of which tested above 4 pCi/l, all 6 of which mitigated. The IBM policy of requiring tests and mitigation if above 4 pCi/l for employees to

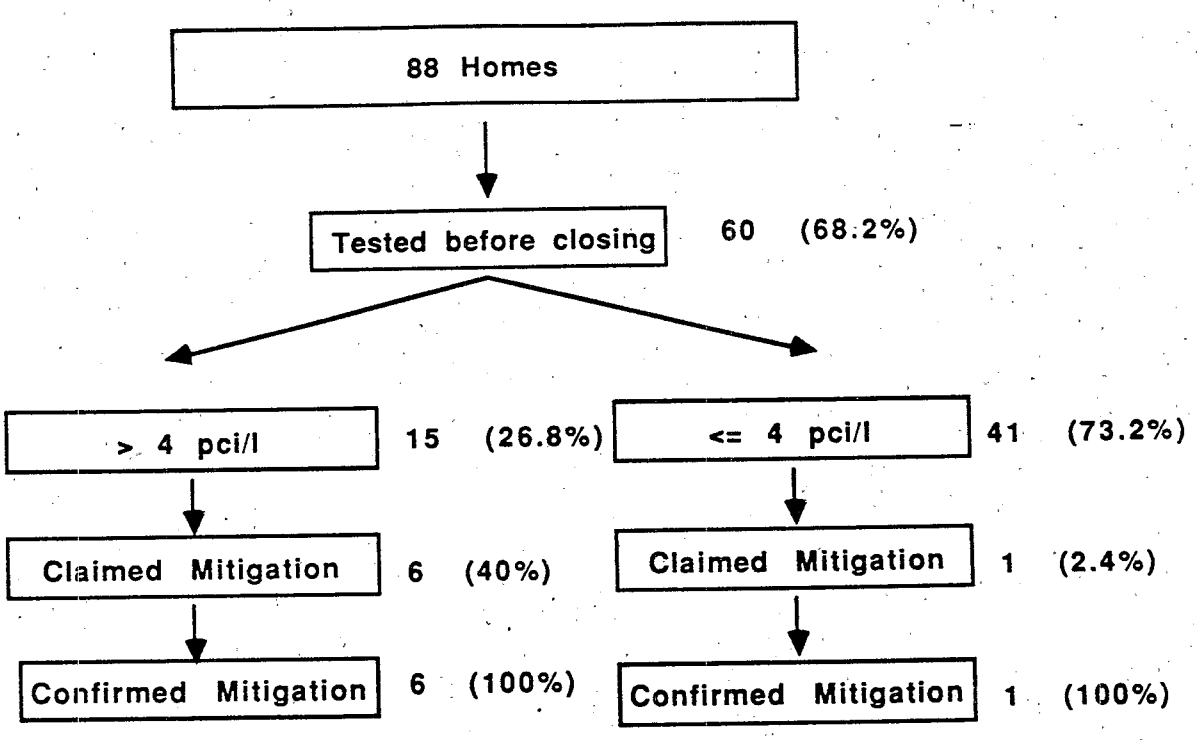

Fig. 3.4. Radon mitigation pathway for 88 home buyers who employed a realtor who gave them radon information, by radon level category. (The percentages for partitioning by radon level category do not sum to 100 because 4 respondents could not report or estimate their radon level.)

participate in their housing buyback program is clearly very effective.

Figure 3.4 charts the pathway for 88 non-IBM homes whose buyers employed a realtor who gave them some information about radon. The testing rate (68.2%) is quite high, indicating that realtors are helping to motivate radon testing. The mitigation rate for those with tests above 4 pCi/l (40%) is good compared to rates among the general population but clearly there is room for improvement -- several people whose realtors gave them advice about radon did not go on to mitigate levels above 4 pCi/l.

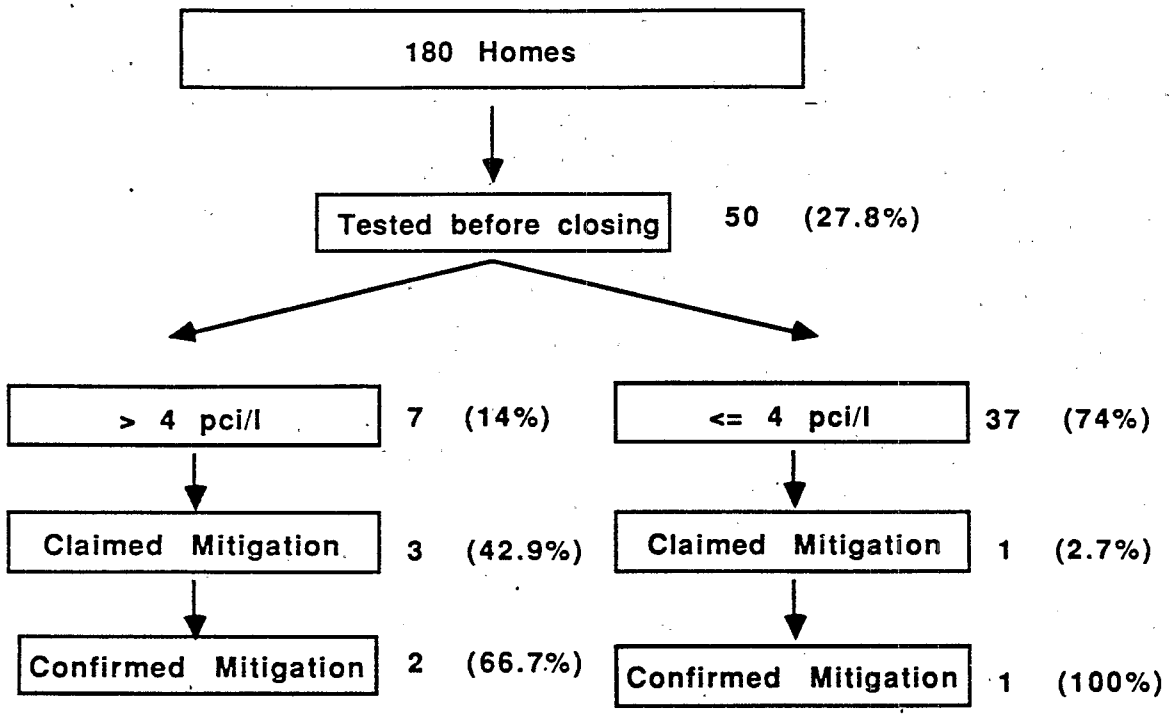

Fig. 3.5. Radon mitigation pathway for 180 home buyers who did not receive radon information from either a realtor or employer, by radon level category. (The percentages for partitioning by radon level category do not sum to 100 because 6 respondents could not report or estimate their radon level.)

Figure 3.5 charts the pathway for the remaining 180 homes for which the respondents did not receive information from either IBM or a realtor. The testing rate for these people (27.8%) is much lower than for the first two groups, but still much higher than that of the general population. These 180 people seem to have not received much of the advantage which the other 123 people gained by being in the time-of-home-sale context.

In fact, what 12 of the 15 people in this study whose homes tested above 4 pCi/l before the sale closed and were subsequently mitigated have in common is personal contact with a professional,

who is knowledgeable about radon, who knows what to do if the house has a radon problem, and who in many instances may be taking some of the responsibility for making decisions about radon off the shoulders of the buyer. This, more than any other characteristic of the time-of-home-sale context, is most likely responsible for the high participation rates we have described.

3.6. Conclusion

In contrast to our conclusions from the previous chapter, provision of radon information at time of sale to home buyers appears to be very effective in inducing both testing and mitigation. In fact, an information and awareness program utilizing realtors as the primary suppliers of information might well make an information only approach attractive for single family homes if one is willing to accept the lengthy delay in resolving the radon problem associated with the slow turnover rate of the housing market. This approach would certainly be cost effective, and the development of better information by EPA for use by realtors would be highly desirable. However, it should be remembered that, in the group motivated by realtor information, 68.2% tested their new homes and of those with "high" radon levels (>4 pCi/l) 40% mitigated. Thus, the overall rate of mitigation was about 27%. This overall rate of mitigation, though far better than that obtained from a general information and awareness program, clearly leaves room for improvement.

Two approaches may work to improve mitigation rates at the time of home sale. First, radon testing and/or mitigation could be required at time of home sale, which would likely yield mitigation

rates similar to those for IBM employees. Second, better information could be made available to realtors either for voluntary use or for use as part of local mandatory disclosure at time of home sale.

Chapter 4

Legal Strategies for Addressing Radon Disclosure at Time of Real Estate Transfer

4.1. Introduction

Radon is a unique environmental contaminant that is difficult to control through traditional pollution control laws and regulations. Because it is naturally occurring and ubiquitous, it cannot be controlled effectively at a "point source" like many air and water pollutants. Since radon contamination generally is not the direct result of any harmful, negligent, or other behavior on the part of a person or organization, it cannot be minimized through a permit mechanism or an enforcement program. Even though the level of radon contamination may be indirectly affected by human activity (e.g., housing design and construction), the natural origins of the gas prevent shifting the cost of radon contamination to a class of persons who caused the harm, because no such class of persons exists. Nonetheless, certain legal strategies, combined with an effective information and awareness program, should be useful in encouraging individuals to take protective measures to minimize their exposure to radon contamination.

Many different radon legal strategies are currently being practiced by both the federal and many state governments, including information and awareness programs, incentive programs, and

regulatory programs (see, e.g., EPA, 1987). Our focus in this chapter, however, will be to address legal issues concerning the strategy for radon disclosure at time of real estate transfer, which the research we have detailed in Chapters 2 and 3 suggests will prove to be the most effective strategy for promoting radon mitigation in the long term.

The remainder of the chapter is organized as follows. Section 7.2 will provide an overview of current federal radon strategies in order to develop the context in which future strategies must be considered. Section 7.3 summarizes those state programs which are relevant to the time-of-real-estate-transfer strategy and may therefore serve as models for similar federal strategies. Section 7.4 then discusses in detail the legal issues surrounding implementation of such a strategy at the federal level.

4.2. Current Federal Strategies Addressing Radon Issues

Congress has not at this time provided the United States Environmental Protection Agency with regulatory power over naturally occurring radon, nor has it adopted incentives, such as tax credits or deductions, to encourage radon mitigation and testing. Congress, however, has required EPA to undertake radon studies and provide information and technical aid to states in the Radon Gas and Indoor Air Quality Research Act of 1986, Pub. L. No. 99-499, §§ 401-405, 100 Stat. 1758-59 (1986) ("Radon/Indoor Air Research Act"), and the Radon Pollution Control Act of 1988, Pub. L. No. 100-551, 102 Stat. 2755 (1988) ("RPCA"). Based on these two laws, the current federal strategies for controlling radon can be divided into two groups: (a)

studying the radon problem and (b) providing information, technology, and other aid to states to assist them in developing radon programs.

4.2.1. Federal Laws

As its name suggests, the Radon/Indoor Air Research Act creates a program to study and assess the indoor radon problem. The Act requires EPA to establish a research program on radon gas and indoor air quality designed to gather data and information to contribute to the understanding of health problems associated with the existence of air pollutants in the indoor environment, to coordinate state, federal, local, and private research, and to assess appropriate federal government actions to mitigate the environmental and health risks associated with all indoor air pollution, including radon. The Radon/Indoor Air Research Act specifies the requirements of this research program, which include research efforts to identify, characterize, and monitor sources and levels of indoor air pollution including radon, control technologies and other mitigation measures, demonstration programs, and information dissemination. This Act specifically states that Congress has not yet authorized EPA to carry out a regulatory program.

Like the Radon/Indoor Air Research Act, the Radon Pollution Control Act does not authorize or create a regulatory program. It is more comprehensive than the Radon/Indoor Air Research Act and contains several interesting provisions directly aimed at state programs. For example, it provides grant assistance to the states to set up radon programs and requires EPA to develop and implement

activities to assist state radon programs. Additionally, this law sets a national goal for the level of acceptable radon in buildings, requires the EPA to update and republish its "Citizen's Guide to Radon" (EPA, 1986a), and orders EPA to develop model construction techniques and standards for controlling radon. A more complete description of the Radon Pollution Control Act and other federal laws appears in Appendix III.

4.2.2. Federal Programs

4.2.2.1. Revising EPA's Citizen's Guide to Radon

The RPCA requires EPA to revise its Citizen's Guide to Radon to include information regarding a series of "action levels" indicating the health risk associated with different levels of radon exposure. Certain "other information" must be provided as well, including a discussion of the increased health risk associated with the exposure of potentially sensitive populations to different levels of radon, the increased health risk associated with radon exposure and risk taking behavior (e.g., smoking), the cost and technological feasibility of reducing radon concentrations, the relationship between short-term and long-term testing techniques and measurements and action levels, and data on outdoor radon levels around the nation. Through the RPCA, Congress also set a national long-term goal to lower indoor radon levels to the same level as ambient air.

Obviously, Congress is very concerned about the health effects of long-term exposure to radon gas. Apparently it feels that information about these health effects was not clearly conveyed in EPA's current

Citizen's Guide. In fact, the House Report explains why Congress mandated the additional information in the Guide:

> The legislative requirement to update the Citizen's Guide is principally based upon the Committee's concern that the public is interpreting radon levels as safe if they fall below EPA's action level of 4 picocuries per liter. The EPA guidance document currently advises that "follow-up measures are probably not required" if screening measurements are less than 4 picocuries per liter. In addition EPA states that "[e]xposures in this range are considered above average for residential structures." The Committee believes that many people have misinterpreted EPA's designated action level and the statements in the current citizen's guide as meaning that there is little or no risk from radon levels below 4 picocuries per liter (H.R. 1047, 100th Cong., 2d Sess. 12, 1988).

Congress' required changes and rationale are significant and may impact other strategies for at least two reasons. First, they suggest that EPA's current "action level" of 4 picocuries per liter will be adjusted downward, i.e., made more stringent. Although Congress did not establish a mandatory radon level, its mandate for a continuously decreasing long-term national goal is likely to be adopted by states, local governments, and others involved in radon mitigation. Thus, if a radon contamination problem is discovered in the future and the decision is made to correct it, more complete, and probably more complex and expensive, mitigation and remediation methods may likely be required to reach this continually decreasing level. Second, the House Report indicates that Congress favors a health-based radon standard over a technology-based one. Accordingly, mitigation methods and techniques will be forced to progress toward this ever decreasing long-term radon goal. This type of "technology forcing" may mean that costly and complex remediation and mitigation

techniques must be employed, at least until reasonably priced mitigation technology can achieve the lowered radon levels.

4.2.2.2. Model Building Codes and Standards

The RPCA also requires that EPA develop model construction standards and techniques for controlling radon levels in new buildings by June 1, 1990. To the maximum extent possible, EPA is required to consult with organizations involved in establishing national building standards and techniques in order to develop these standards. The Act does not require states to adopt these model building codes and standards, but it does instruct EPA to give preference for grant assistance to states that have made reasonable efforts to ensure the adoption of these standards.

While not requiring that state and local governments adopt these building standards, by withholding funding from states that do not make "reasonable efforts" to adopt them, Congress has sent a clear signal that it expects the standards to be adopted. Thus, Congress has sent the message to the states that making new buildings radon-proof should be a high priority.

4.3. Current State Real Estate Transfer Strategies

Two complementary real estate transfer strategies have been considered or adopted by some states: (a) contract notification, which can be a general warning of the radon threat, a required disclosure of previous test results to prospective buyers, or the requirement of radon testing prior to the final execution of a contract; and (b)

contract nullification or new owner reimbursement for remedial costs when prior notification was not given. Florida, Maine, New York, New Jersey, and Rhode Island have considered legislation that would require warnings or disclosures to prospective real estate buyers, renters, or lessees. To date, only New Jersey, Florida, and Rhode Island have passed such legislation. The state of Maine has considered legislation that would allow the buyer to nullify a real estate contract if notification of a radon problem is not provided. The New York state legislature debated the question of reimbursement to new owners for radon remediation if previous owners or realtors failed to disclose a radon problem. No state has yet adopted such legislation. The next few sections provide detailed information for some of these state programs.

4.3.1. Florida

As of January 1, 1989, Florida requires notification of the potential radon threat in at least one real estate document. The notification must read as follows:

> RADON GAS: Radon is a naturally occurring radioactive gas that, when it has accumulated in a building in sufficient quantities, may present health risks to persons who are exposed to it over time. Levels of radon that exceed federal and state guidelines have been found in buildings in Florida. Additional information regarding radon and radon testing may be obtained from your local county public health unit.

4.3.2. Rhode Island

Rhode Island passed a law in June 1988 requiring that, among other things, by January 1, 1989, all real estate contracts must contain the following language:

> Radon has been determined to exist in the state of Rhode Island. Testing for the presence of radon in residential real estate prior to purchase is advisable.

4.3.3. New Jersey

New Jersey law requires that "[i]n the case of a prospective sale of a building which has been tested for radon gas and radon progeny, the seller shall provide the buyer, at the time of the contract of sale is entered into, with a copy of the results of that test and evidence of any subsequent mitigation or treatment, and any prospective buyer who contracts for the testing shall have the right to receive the results of that testing." In reaction to this law, New Jersey realtors have incorporated testing provisions into the real estate transaction. They require the seller to test before the sale, and the buyer to test immediately after the sale. If remediation work is needed, it is funded out of an escrow account set up by the seller and buyer before closing. A pending state bill (S. B. 2964) would require the completion of radon tests as a condition of real estate transfer.

4.3.4. Maine

The state of Maine proposed but did not pass notification legislation for certain real estate documents. The proposed Maine notice (L. D. 552) was written as follows:

> Naturally occurring radon gas may pose a health hazard in residential dwellings. Testing services are available from the Department of Human Services, Public Health Laboratory, Statehouse Station #11, Augusta, Maine 04333.

This proposed legislation was designed to warn Maine residents of possible radon health risks and to establish penalties for real estate agents and home sellers neglecting to inform buyers of the notice.

A second bill, the Radon Gas Liability Act (L. D. 965), was introduced to the Maine State House of Representatives in 1987 but also did not pass. One proposal in this bill would have rendered any real estate contract null if radon tests revealed concentrations greater than 4 pCi/l in the building being considered for sale and if the purchaser wished to nullify the contract as a result.

4.3.5. New York

A major piece of legislation proposed in 1988 is still pending in the state of New York. Assembly Bill 10293 would amend Article 20 and Sections 600-602 of the New York real property law to include a radon disclosure notice. The notice would appear on all residential property contracts and would read as follows:

RADON DISCLOSURE NOTICE

> Radon is an odorless and colorless radioactive gas identified as a leading cause of lung cancer. It may be released naturally in the ground in locations throughout New York State. Radon can seep into homes and accumulate to dangerous levels. The buyer should be aware that indoor radon levels can be determined by proper testing and, where necessary, remedial steps can be taken to correct the problem. These steps may include sealing the foundation or ventilating the basement. The parties to this contract may negotiate concerning the allocation of the costs of detecting and correcting any identified hazardous radon gas problem. For further information on radon contamination, contact federal, state or local health or environmental agencies.

In cases in which such notice is not provided, New York's proposed legislation would make sellers liable to buyers for the reasonable costs of radon detection and remediation occurring within one year of the date of property transfer. Moreover, another proposal in New York would allow the nullification of any new real estate contracts when a home tests above 4 pCi/l.

4.4. Radon Disclosure at Time of Real Estate Transfer

In this section we set forth the radon control strategy we believe offers the most promise for promoting effective mitigation: mandatory radon testing and disclosure during real estate transactions. We will discuss the advantages and disadvantages of this strategy based on the following six criteria:

1. effectiveness -- whether the strategy can achieve the goal of lowering exposure to radon;
2. cost -- whether governmental resources are associated with implementation of the strategy;

3. equity -- whether the strategy distributes the costs fairly among individuals affected by it;

4. legality -- whether the strategy conflicts with other principles of law, such as constitutional law (see Appendix IV for a detailed analysis of federal constitutional issues);

5. federalism -- whether the strategy affects the relationship between the states and the federal government; and

6. enforceability - whether the strategy can be policed to ensure its efficacy.

The time-of-real-estate-transaction regulatory approach is a flexible, multifaceted, yet powerful strategy under which the government can require or recommend varying degrees of disclosure, testing, or mitigation including (a) general disclosure of the potential of radon gas and its effects, (b) specific disclosure regarding known levels of radon gas, (c) recommended or required testing for radon contamination, (d) recommended or required mitigation, if appropriate, or (e) voiding of the purchase and sale.

To analyze this strategy, we divide real estate transactions into five categories and subdivide one category, home sales, into chronological subcategories. The five categories are as follows:

1. a sale of a residence or building;

2. a lease of a residence or building;

3. a financing action after the rental, or home or building sale, such as a home equity loan, improvement loan, or second mortgage;

4. issuance of a building permit for modification of existing or new structures; and

5. issuance of a final "certificate of occupancy" or a final inspection for new structures.

The sale situation will be discussed at length. Because the steps involved in leasing, financing, and issuance of a certificate of occupancy are analogous to steps in the sale process, these categories will be discussed only briefly.

Before examining these specific strategies, however, some general observations can be made about intervention during the real estate transfer process. Assuming that the information disclosed at the stages suggested below is accurate and that the parties involved in the real estate transaction comprehend the information, such strategies can be very effective in ultimately reducing nationwide exposure to harmful radon levels. The strategies could have a broad impact because the vast majority of building and homes are eventually bought and sold through the services of real estate agents, inspectors, and mortgage institutions. The strategies may also be considered optimal from an economic perspective, because affected parties are allowed to bargain freely about the economic and health risks of radon exposure. Although the strategies have the advantage of low costs for the regulatory agency, certain nontrivial costs for testing and paperwork would be imposed on sellers, realtors, and mortgage bankers.

The notable advantage of these real estate transaction strategies is that during the sale process, buyer, seller, and the supporting financial institutions (e.g., mortgage companies) have a heightened awareness of risks to property and will be motivated to obtain and disseminate accurate information and/or to undertake remediation. Also, real estate transaction strategies provide an appropriate vehicle

for translating health risks into economic terms in a way that may encourage mitigation that would not otherwise occur.

The effectiveness of real estate transaction strategies might, however, be hampered by certain factors. For example, success would depend on the availability of reliable test methods. Radon has become a national issue only recently, and testing and mitigation methods have not been fully developed. The fast pace of most real estate transactions requires accurate short-term test methods that may not yet be available. Perhaps, more importantly, a safe level for exposure to radon has not yet been established. Congress only recently declared it a national goal to reduce indoor radon levels to the same levels as ambient air (see Appendix III). Without an agreed upon level of safety, it is extremely difficult to determine an appropriate level for mitigation or to determine the real devaluation properly attributable to a radon problem. This uncertainty might disrupt real estate transactions, with or without required disclosure, testing, or mitigation, although the evidence presented in Chapter 3 suggests this is unlikely. The success of these strategies also may depend on the development of certification criteria for radon testing and mitigation companies. The assurance of minimum qualifications of those involved in the radon service industry is crucial to provide confidence about the information exchanged in the real estate negotiation process.

The place at which the federal government might most appropriately intervene in the real estate transaction process is in the second mortgage market, when mortgages are resold to financial institutions which are often located in a different state than the original lender and therefore naturally fall under federal jurisdiction,

although intervention at other points may also be feasible. However, any federal intervention in the real estate transaction process must be measured against the potential constitutional concerns (e.g., tenth amendment) that might arise in the event these strategies are federally implemented (see Appendix IV). With these general observations in mind, the potential strategies and their merits can be examined.

4.4.1. Sale of a Home or Building

The sale of a home or a building is perhaps the most opportune time to implement a real estate transaction strategy. For purposes of analyzing this approach in greater detail, we have divided the sale into five periods: (a) the pre-sale period, during which the buyer generally reviews homes with the realtor; (b) the negotiation period, during which the buyer and seller discuss, and agree upon, the terms of a sale; (c) the contract signing and inspection period, during which the buyer signs the purchase contract, seeks financing, inspects the seller's premises, and generally gathers information about the property; (d) the final inspection and the closing, when the buyer inspects the premises immediately before closing, and closes on the premises; and (e) the post-closing period, at which time the buyer purchases the property and takes possession.

4.4.1.1. Pre-sale Period

During the pre-sale period, a buyer generally "goes to the market" by contacting a real estate agent. The buyer and agent

preview buildings or homes so the buyer can select potential premises for purchase. While it is probably inappropriate to require realtors to conduct testing or mitigation, requiring the real estate agent to provide information with respect to radon levels, testing, and/or mitigation at this point might be an effective disclosure approach. (As described in Chapter 3, many realtors are already taking it upon themselves to disclose radon information to their clients.) The real estate agent would bear the burden of determining if the property had ever been tested, and if so, the results of the test. A realtor might be subject to suit upon breaching the obligation to inform or disclose.

While imposing such a condition upon real estate agents may seem burdensome, it is not unreasonable. Realtors act as agents for the seller and generally are familiar with the community. They occupy a position of trust with respect to both the seller and buyer, who rely upon their expertise. Furthermore, realtors have created a database containing detailed information about sale properties called the Multiple Listing System (MLS). Thus, an appropriate notation in the MLS system could inform all realtors that a parcel of property contains radon or has not yet been tested. Disclosure at this early stage allows the buyer to learn about radon and to consider whether to accept the risks associated with long-term exposure.

Disclosure by realtors has other advantages. It is cost-effective for the government, because the real estate agents are shouldering the expenses related to the disclosure requirements. This strategy also puts disclosure in a context that the seller and buyer can understand; radon becomes associated directly with the sale and purchase of a home or building. It is not difficult to enforce, because disclosure can

be determined by reviewing any written materials given to the buyer by the real estate agent, or by asking about oral warnings provided by the realtor. This approach is relatively comprehensive because the majority of property sales involve a realtor, allowing a wide audience to be reached. Realtors may add a disclosure clause to the standard purchase contract for homes in order to fulfill this disclosure requirement, they may prepare a separate information booklet on radon, or they may use "safe harbor" forms.[17]

The major disadvantage of this trategy is the burden it places upon real estate agents. Depending on the type and extent of disclosure required, it may force realtors to require sellers to conduct a radon test, or mitigate, before a building or home is listed for sale. More importantly, if the buyer later discovers high radon levels, this strategy could create liability for realtors who, in good faith, relied upon assertions by the seller that radon was not a problem at the premises. Some of these inequities can be cured by requiring or recommending that the realtor provide only a generic or standardized written notice to the buyer (although evidence suggests it may be important that a test be required). Such a notice could state simply that radon is a colorless, odorless gas that may cause lung cancer, and that it may be appropriate to test property for radon contamination. Two states (Rhode Island and Florida) have enacted such general radon notices for real estate transactions (see Sections 7.3.1 and

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[17]By using safe harbor forms, which set out a checklist of potential hazards for which real estate agents must inspect, realtors can be more confident that they have fulfilled their disclosure obligations and protect themselves from liability.

7.3.2). Such a notice might lead the buyer to engage in the necessary self-protective behavior. The seller, knowing that the buyer is to receive such a general disclosure, is more likely to test the home or building and conduct remedial action before attempting to sell it.

Such a pre-sale disclosure strategy could be very effective in encouraging widespread mitigation because most real estate transactions involve a real estate agent. This strategy would significantly increase the distribution of information to buyers, who have the biggest incentive to evaluate it carefully. Delivery of this information personally and directly by a real estate agent also would increase seller and buyer awareness. Also, real estate agents would themselves have an incentive to learn about radon so that they can advise their clients and so that the radon issue does not greatly interfere with the sales process. And, disclosure at this early stage in the sale process still allows substantial time for further inquiry, testing, evaluation, or mitigation.

4.4.1.2. Negotiation Period

The negotiation period generally involves three parties: the seller, the buyer, and a realtor. During this period, the buyer has tentatively decided to purchase the premises and approaches the seller with an offer to buy. Generally, negotiations ensue over the terms of the sale, including the purchase price, time of closing, and other conditions and contingencies. At the end of the negotiation period, seller and buyer agree on the terms of purchase.

The negotiation period is the most obvious period in which the radon disclosure/testing strategy may be utilized, because it is during this period that seller and buyer are evaluating all of the factors relevant to the sale. Seller and buyer are assigning a monetary value to such factors and making decisions about them. During the negotiation period, the radon contamination would likely be quantified by the seller and buyer with respect to the purchase price of the premises. Thus, the final agreement would reflect the diminution in the value of the premises because of the radon problem.

There may be one potential drawback to disclosure without required mitigation at any point in the sale process. Assuming the buyer understands the risks associated with exposure to radon, allowing the seller and buyer to negotiate about the radon levels means that the buyer may accept a trade-off by willingly purchasing a radon-infested home for a lower cost despite the potential health effects of long-term exposure to radon. If the aim of any radon strategy is to encourage self-protective behavior and correct radon contamination, then disclosure without required mitigation may not reach this goal. However, the evidence presented in Chapter 2 suggests that mitigation is nearly always the option chosen. Alternatively, forced mitigation at the time of sale is problematic. First, it requires that some level of mitigation be agreed upon by seller and buyer or set by the government. Second, if the government sets a required mitigation level, it could reduce the market value of the premises to such an extent that the seller can argue that the property was unconstitutionally taken without just compensation (see Appendix IV for a discussion of the takings issue).

The real estate negotiations process is one of the most effective times during the home sale process for encouraging or requiring disclosure, testing, or mitigation, because the parties are focusing on the economic aspects of the transaction, are highly motivated to obtain detailed information about the building or home, yet still have time, if necessary, to undertake additional testing or evaluation or mitigation. During this stage, information about any radon contamination can be readily translated into concrete economic terms and can become another factor in negotiations over the price. And, in the event that testing is incomplete or uncertain, the parties can add contingency clauses or allocate future potential liabilities.

4.4.1.3. Contract Signing and Inspection Period

The contract signing and inspection period begins when the contract for sale is signed and the buyer begins the search for financing the sale, and it ends after the buyer has gathered information about the premises and conducted a building or home inspection before closing. Thus, this period mainly involves the buyer, the financial institution providing the mortgage, and the individuals who gather facts and conduct various inspection services for the buyer (e.g., home or building inspector).

The mortgage process also is one of the most effective avenues for required or recommended testing or disclosure. Because financial institutions have a strong interest in protecting the market value of collateral, as a condition of the mortgage, mortgagees may provide

radon information to the mortgagor[18] or require mortgagors to certify that radon levels are within a certain range and/or to test for radon and take remedial action, if appropriate. Because most home purchase contracts contain a contingency clause permitting the buyer to void the contract without penalty in the event that a mortgage cannot be procured, a home buyer discovering radon contamination would not be penalized for failing to procure a mortgage because of a radon problem. A seller who lost a home or building sale because of radon would be encouraged to mitigate the problem in order to increase the sales potential of the building or home.

Involving financial institutions in a strategy to increase disclosure, testing, and mitigation may be the most powerful method of intervening in the vast number of real estate transactions. Because obtaining the mortgage is typically the "make or break" point of a building or home sale, both seller and buyer have strong incentives to comply with whatever the mortgagee requires. More importantly, the purely economic interest of the mortgagee in properly evaluating the value of the property and in preventing subsequent devaluations (such as the latent discovery of high radon levels) would motivate financial institutions to ensure that comprehensive and accurate information was disclosed. An additional benefit also may be that the collective

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[18] For example, the federal government could require that all federally financed mortgagors be provided an information booklet explaining the impact of radon contamination and notifying them that mortgagees may consider test results (or lack of them) and mitigation efforts as a factor in setting the terms of the mortgage. A similar disclosure and booklet scheme is currently used by the federal government with regard to real estate settlement costs. (See the Real Estate Procedures Act of 1974, 12 U.S.C. 2601, 2604(a), (c).).

economic weight of mortgage institutions creates larger incentives for accurate testing, innovations in mitigation methods, more thorough information dissemination, and better assessments of health risks.

Generic or standardized disclosure by the persons who conduct home or building inspection services may have a positive effect. Arguably, it is somewhat late in the sale process to begin testing or mitigation because the purchase contract has been signed and the sale process is almost complete. For example, while conducting the home inspection, the inspector can ask the buyer whether there has been any attempt to assess radon contamination. Inspectors can also inform buyers of structural and/or other characteristics of the premises that indicate a potential radon problem, such as a completely underground cellar that creates a negative pressure likely to draw radon into the home, or granite or other geological formations upon which the premises are built. The major drawbacks of this strategy are analogous to the drawbacks of using realtors as disclosure agents, i.e., it may be unduly burdensome and provide the basis for potential liability. Additionally, home inspectors may not be trained to detect and assess potential radon risk factors and thus may provide incomplete, inaccurate, or false information.

The effectiveness of requiring radon consultation to be included in the inspection process would depend largely on the training and qualifications of the inspectors. Nonetheless, because inspectors are generally hired by the buyer, the buyer would have an incentive to conduct a thorough examination, which the buyer could then carefully evaluate. This strategy could provide an effective double-check on any information provided by the seller. And, because inspections are

routine for virtually all home and building sales, this strategy could reach the vast number of homes and buildings involved in real estate transactions.

4.4.1.4. Final Inspection and Closing Period

The final inspection and closing period includes the final "walk-through" immediately before closing and the closing ceremony itself, in which the appropriate documents are executed and, if necessary, attested to. The major actors during this period are the seller, the buyer, and their attorneys.

Again, as discussed with respect to the contract signing and inspection period, the seller's disclosure to the buyer is probably not an appropriate strategy at this stage. Mandatory or recommended testing or mitigation probably is not feasible. One potential strategy, which is a type of disclosure, could be to place a warranty or warning into the deed. The warranty, given by the seller to the buyer, could state that, to the best of the seller's knowledge, the premises are not contaminated with radon. It could state that the seller has tested the premises and list the date of the test, the level of radon discovered, and the company that conducted the test. The warning, placed in the deed, could contain the same statements as the warranty or it could contain a generic disclosure statement about the risks of radon. These warnings or warranties could provide the buyer with a strong cause of action against the seller if they proved false. Moreover, a warning in the deed would notify any future purchaser of the radon-related conditions. Thus, the next buyer's lawyer, examining a deed, would

alert the buyer about radon. While the use of warnings or warranties would not be an effective strategy for the present parties to the negotiations (because bargaining at this point is essentially finished), such provisions could be an effective tool for informing future buyers of the property's radon risk. With this long-term view in mind, this strategy could be uniquely effective.

4.4.1.5. Post-closing Period

The post-closing period begins when the closing is completed and continues until the premises is sold again. The buyer, now the property's owner, is the only individual directly connected with the premises.

Disclosure, mandatory or recommended testing, and other strategies would not be effective in altering behavior that has occurred in the past. Nonetheless, empowering the buyer/owner to recover costs of mitigation and/or testing from the seller if the buyer/owner discovers high radon levels after taking possession may be a strategy to employ during this period.

This strategy has many potential disadvantages. It probably depends on litigation, which is expensive, uncertain, and time consuming; it may be difficult to prove that the seller falsified test results or conducted an inadequate radon survey, because radon levels fluctuate dramatically over time. There is also no guarantee that any amount recovered by the buyer/owner would be spent on radon mitigation. Nonetheless, the major advantage of this approach centers on its potential deterrent effect. Because it severely punishes the

seller's failure to determine and/or disclose radon levels, sellers will be more likely to carry out required or recommended radon testing and disclose the results.

4.4.2. Lease of a Residence or Building

The same approaches presented above involving the sale of a home or building could be applied in the context of negotiating a lease. For example, the government could require or recommend disclosure by a realtor, insertion of a "radon clause" in the lease agreement, or condition financing on testing and/or mitigation. Particularly because leasing of commercial buildings is pervasive, this avenue for addressing the radon threat should be considered an important supplemental strategy.

The main distinction between the lease situation and the sale situation is that (depending of course on the term of the lease) the parties may have less of an interest in testing, disclosure, and/or mitigation, because they may be only thinking of the short-term economic consequences of the transaction. On the other hand, because the lessor and lessee have an ongoing relationship through the end of the term (and, by the exercise of options, perhaps beyond), the time pressures inherent in the sale negotiations context may be partially removed. For example, compared to a buyer, a lessee could more easily agree to condition the amount of the rent on the results of long-term or periodic testing for radon contamination. Lessees also could obtain a clause providing that expenses for mitigation are deducted from the rent. As with sales, the success of this strategy

would depend in great part on the quality of information available to the parties and their own economic evaluation of the health risks involved.

4.4.3. Financing Action after the Home or Building Sale

Another point at which a radon strategy could be implemented is during a financing action after the home or building has already been sold, e.g., when the buyer applies for a home equity loan, a home improvement loan, or a second mortgage. The analysis outlined above with regard to mortgages would apply in these situations as well. At this stage, a strategy of recommended or required testing, disclosure, and/or mitigation could be effective in encouraging owners to reduce their exposure to radon. The unique advantage of this strategy, of course, is that it reaches buildings and homes not involved in sale or transfer. Even though only a small percentage of buildings or homes may be affected by this strategy, it is a logical complement to the transaction-based approach discussed above.

4.4.4. Issuance of a Building Permit

State and local laws generally require that building permits be obtained for new structures and for certain modifications of existing buildings or homes. It is at this point that building code and other structural requirements minimizing radon exposure could be imposed. For example, building plans could be evaluated for ventilation systems, structure of underground areas, floor construction, and weatherization techniques. The soon to be drafted model building code (see

Appendix III), which states are encouraged but not required to adopt, provides national leadership for this strategy.

Because construction cannot legally proceed without a permit, the owner may face "red tagging" delay, and possible fines for attempting to circumvent the permit system. Thus, restrictions on building permits would be an effective technique for ensuring that at least new and modified structures are radon safe if not radon proof.

The primary advantage to such a strategy is that it is preventive in nature. It would be relatively easy to enforce, because radon mitigation measures would simply become another design requirement for architects and contractors. The social costs of such a policy also would be low for those houses which need mitigation because, at least for new structures, no radon problem yet exists and no costly post-construction remediation would be required. However, considering that the large majority of houses do not require mitigation, the social costs of the policy may be high in the sense that costs must be imposed on many homes which have low radon levels in order to find the homes which have high radon levels.

The main disadvantage to permit requirements is that it may be difficult to achieve concensus concerning the appropriate building code requirements. And, because structural design, though important, is only one element that determines potential radon exposure levels, this strategy cannot address or anticipate the largely natural causes of contamination (i.e., the geologic composition of the area).

4.4.5. Issuance of a Final Certificate of Occupancy

Requirements for disclosure or for testing or mitigating radon contamination levels could also be imposed during the issuance of a final certificate of occupancy or a final inspection for new structures. As discussed above with respect to the final inspection during the sale process, this stage is probably not an appropriate time to impose a primary radon strategy. Particularly with regard to new structures, because the certificate of occupancy and final inspection occur after the completion of design and construction, the flexibility of an owner to respond to new requirements is limited and the costs may be high. On the other hand, actual radon exposure levels may not be ascertainable until after a structure is completed. If such a strategy accounts for these latent problems, then requiring testing and/or mitigation prior to occupancy could be a very effective secondary strategy for enforcing exposure goals.

4.4.6. Mandatory Testing or Mitigation of Public Buildings

The radon disclosure during real estate transaction strategies outlined above, if properly implemented, will address the majority of radon problems in homes, and a large number of radon contamination problems in buildings. Because these real estate strategies hinge upon property transfer, however, they will not be successful in addressing premises which are not generally sold, leased or otherwise transferred. Also, the real estate strategy may be inappropriate for transfers involving state or federal governmental entities because applying the approach to a governmental body may be inappropriate as

a matter of law. Thus, there is a category of "public buildings" which would require application of a different strategy as a supplement to a real estate strategy. This section focuses on one category of public buildings: governmental or quasi-governmental structures.[19]

A potential federal strategy applicable to governmental or quasi-governmental facilities could involve the mandatory testing and disclosure of results to the occupants of these buildings. Mandatory mitigation is a second option aligned with this strategy.

Mandatory testing of governmental and quasi-governmental facilities would depend largely upon intra- and intergovernmental cooperation. Mandatory testing of these premises is easier to administer than mandatory testing of privately owned, operated, and occupied property because the government can easily carry out the testing on its own property, or exert its will to require testing. For example, because there are no private parties involved, a facility which is owned or operated by a state government can be tested easily if the state legislature requires testing of public buildings. For a structure leased or occupied by a governmental entity, the government can

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[19]A public building includes the following three categories of real property: (a) governmental or quasi-governmental structures, the majority of which are buildings owned, operated, or occupied by the federal or state government and containing federal or state government facilities, especially offices; (b) public accommodation facilities, which are facilities used by members of the public, or open to members of the public, such as a museum, library, sports arena, or concert hall; and (c) "special population" facilities, such as hospitals, mental institutions, schools, day care centers, or prisons. This section of the report does not address public accommodation facilities or special population facilities. Although strategies applicable to these two types of public buildings should be analyzed, they are outside the scope of this report.

exert its bargaining power to include in its lease a clause regarding testing.

By restricting testing to governmental or quasi-governmental facilities, the federal government would not impose financial, legal, or other inequities or burdens on private citizens. A mandatory testing program would demonstrate the government's commitment to the seriousness of the radon problem, and would serve as a model for citizens to follow. Thus, testing by the government could be a valuable public relations tool.

But testing alone may not be sufficient. Testing without mitigation uncovers radon contamination without resolving it. However, disclosure of the test results may motivate the building occupants to demand mitigation and follow-up testing, and may encourage others to demand testing and disclosure.

The potential cost of requiring testing is the major disadvantage of this strategy. But required public testing may be a necessary cost to increase citizen confidence in government declarations of the radon threat, and to demonstrate that the radon problem requires prompt action and the government is prepared to take such action. In fact, without an investment in public testing, the federal government may undermine the value of their other radon investments by sending an ambivalent message to citizens. In addition, mandatory public testing guarantees that the federal government will learn the full extent of its portion of the radon problem.

Required mitigation of radon contamination can be combined with the mandatory testing requirement. Though the costs of mandatory mitigation are high, the potential benefits are great. First,

mandatory mitigation would establish the federal government as the leader on radon remediation. Second, the occupational health threat would be reduced or eliminated, thus protecting workers. Third, required mitigation could inspire private mitigation. Fourth, mandatory mitigation allows the government to test new remediation techniques.

Aside from cost, the disruption caused by mitigation construction is the only other serious disadvantage of this strategy. Required mitigation also is sure to attract publicity, increasing the likelihood that mitigation target levels adopted for governmental and quasi-governmental buildings will then be applied to private buildings. Thus, public mitigation efforts may eventually compel the government to establish defined levels of acceptable radon exposure.

Chapter 5

Conclusion: An Evaluation of Strategies for Promoting Effective Radon Mitigation

5.1. Introduction

The purpose of this study has been to evaluate the effectiveness of alternative strategies for motivating people to test for radon gas in their homes and to mitigate if necessary, and we have conducted surveys which evaluate two of these strategies: (a) a traditional information and awareness strategy aimed at the general public and (b) a strategy which discloses radon information (and perhaps requires testing) at the time of home sale. A review of the literature on risk communication and motivating self-protective behavior suggests that traditional information and awareness programs will likely fail when they are targeted at the general population. To test this conclusion from the literature we sent a mail survey to 920 households which had purchased radon test kits as part of an intensive information and awareness campaign in the Washington, D.C. area (see Chapter 2). Although we estimate that about 33,000 homes in this area exceed the federal guideline by a factor of five or more (had a radon reading of 20 pCi/l or higher), the survey results indicate that only 1.2% of this group have taken convincing remedial action as a result of the campaign. Those few homeowners who tested were sent reprints of two EPA documents, "A Citizen's Guide to Radon" (EPA, 1986a) and

"Radon Reduction Methods: A Homeowner's Guide" (EPA, 1986b). Unfortunately, our results suggest that these pamphlets may have encouraged people to try their own remedial measures rather than employ a professional contractor. These home remedies (e.g., opening basement windows more often) were not followed by retesting to verify their effectiveness in spite of clear warnings given that single limited remedial measures are likely to be ineffective.

In contrast, a telephone survey of 303 home buyers in Boulder County, Colorado found that over 40% of recently purchased homes were tested for radon gas at the time of home sale and that this testing was often motivated by information provided by the realtor (see Chapter 3). Even though no intensive information and awareness campaign had been conducted in Colorado and there are currently no state laws in effect concerning radon, 54% of tested homes in our sample which had radon levels above the EPA action level underwent mitigation (with 87% of those completing follow-up testing) as part of the home sale transaction. These results suggest that a radon information and awareness program targeted at the point of home sale, when the transaction context provides a strong economic incentive to repair any problems a home might have, could be highly effective in comparison to information targeted at the general population. Since several approaches for mandating disclosure of radon levels at the time of home sale appear to be available to the federal government (see Chapter 4), a regulatory approach may be the most effective available strategy.

EPA is currently limited to supporting information and awareness through such means as its "Citizen's Guide" and "Radon

Reduction" pamphlets. Our study suggests that these materials require substantial revision and that new materials specifically targeted at realtors and home buyers would be highly desirable, especially in concert with mandatory disclosure.

The remainder of this chapter discusses three potential radon strategies:

1. Information and Awareness: Programs or strategies whose primary purpose is to inform property owners or occupants of the potential problems of radon gas in buildings.

2. Economic Incentives: Programs or strategies using financial inducements to motivate owners or occupants to take personal action against radon.

3. Regulation: Programs or strategies which involve setting rules, standards, and procedural guidelines to make responsible parties take action against radon.

5.2. Information and Awareness

A large amount of research has been conducted on risk communication and on motivating self-protective behavior. Although there are still large gaps in our understanding of many issues, there are some substantive conclusions that yield recommendations for radon risk communication.

First, it must be recognized that different people define risk in different ways. For example, experts commonly judge risk in terms of probabilities and losses, whereas laypeople commonly have a much broader definition of risk which includes such factors as whether the risk is controllable or uncontrollable, voluntary or involuntary, natural or technological, or known to science or unknown. Different people

also have different goals concerning risks and are interested in different information. For example, risk managers are usually concerned with the aggregate risk to a large population, whereas laypeople want to know what they should do, individually, to protect themselves and their family.

Second, people commonly have great difficulty when judging probabilities, making predictions, coping with uncertainty and, in general, thinking intuitively about risk. They typically rely on judgmental heuristics which can lead to systematic biases and errors in judgment. For example, people often judge the frequency of an event by its availability, that is, the ease with which examples of the event can be imagined or recalled. For a risk which lacks perceptual reminders, for which prior experience is benign, and for which deaths occur singly and in isolation, such as radon, availability is low and the risk is commonly underestimated. People also generally fail to understand the limits of their knowledge. For example, people often erroneously believe they can exert control over events that are in fact random and they often display too much confidence in their ability to estimate uncertain quantities.

Third, naive beliefs concerning risky events tend to be very unstable, especially when the risk is new and unfamiliar. Such beliefs can often be easily manipulated by seemingly subtle differences in the way in which risk components such as outcomes and probabilities are framed. For example, people dislike suffering losses more than they like receiving gains and may take different actions depending on which perspective they are encouraged to adopt.

Fourth, people have the most difficulty when judging very low probability risks (for example, less than 1%). The distribution of people's decisions for low probability risks is commonly bimodal, with one mode at or near a level indicating no concern for the risk and a second mode at a level indicating overconcern for the risk.

A radon risk communication program must take into account what is known about how people define risks, how they judge risks, how they respond to alternate framings of risk, and how they interpret probabilistic information. However, it should be noted that radon has a profile of characteristics that would be expected to lead people to underestimate its associated risk or even to dismiss it entirely, which will make an information and awareness approach very difficult. The risk is objectively below the level at which people commonly respond accurately, the consequences of the risk are far removed from the exposure, and deaths related to the risk occur in isolation and are impossible to relate directly to the hazard. Also, radon is a naturally occurring risk for which no one can be blamed and people's prior experience with the risk is overwhelmingly benign. Since radon is colorless and odorless, there are no perceptual reminders to alert people to the presence of the risk. Finally, the risk varies widely depending on time of year, geographical location, behavior patterns, and other factors, making it difficult, if not impossible, for people to assess their risk very accurately.

Although the test to determine the risk from radon is relatively quick and inexpensive, several other characteristics of the radon testing and mitigation process are likely to discourage appropriate protective responses. For example, there is little time urgency for

conducting the test, and the results of the test can only bring bad news compared to the status quo. Also, interpretation of the test results is subjective and open to question, and people are likely to view remediation as costly and difficult. Due to the technical nature of radon testing and mitigation, most people will be forced to rely on the opinions and advice of others. In fact, to ensure protection against radon people must engage in a long, drawn out, complicated series of behaviors with the opportunity to drop out at each step along the way.

Finally, several characteristics of the current social context have implications for the radon problem. People are now being bombarded by information concerning a large number of low probability risks, and the radon issue may not be a very high priority for many people. Also, the same factors that lead to apathy on the part of individuals make the radon problem uninteresting for the mass media and unlikely to be consistently in the news. In addition, unlike most environmental risks, radon is largely under the control of individual homeowners, and risk communication must reach down to this level.

A large amount of research in such domains as health, natural hazards, crime prevention, injury prevention, and energy conservation has been conducted on ways of encouraging and motivating self-protective behavior. Although researchers are only beginning to explore commonalities among these different domains, experience with real risk communication programs has yielded a variety of recommendations applicable to radon risk communication.

The major result of this experience is that, despite an overwhelming general interest in self-protection on the part of both professionals and the public, it is enormously difficult to get specific

people to perform specific behaviors in specific situations. Well-intentioned, common sense suggestions are often ineffective, and simply dispersing information and increasing knowledge is usually insufficient to motivate people to act. Also, people's behavior seems to be largely governed by short-term consequences, and they are very reluctant to accept definite costs in the present to prevent indefinite harm in the future. Finally, self-efficacy, that is, a person's beliefs concerning his or her ability to perform an action and its chances for success, appears to be a very important determinant of protective behavior -- attention must be paid not only to generating concern about a risk but to providing easy solutions that individuals can be confident of handling themselves.

Traditional information and awareness campaigns and fear-arousing appeals have proven to be generally ineffective, in and of themselves, in motivating people to act. There are, however, two approaches to communicating risk that appear to be relatively promising. The first approach uses knowledge from decision theory to communicate or frame risks in an effective manner. For example, we have experimented with communicating a low-probability risk as an integration over time where people can act to protect themselves from the risk for a long period of time. The results of the experiment show that framing a protective behavior as a single decision that covers a long span of time results in more accurate, more consistent, and less variable responses to risk. The second approach, social diffusion, applies knowledge gained from the study of how new information is commonly diffused through a social system. A typical program first identifies social referent groups and preexisting

channels of communication and then identifies and activates innovators and opinion leaders and seeks their help in dispersing information to other members of the system. Such social diffusion programs have already been shown to be more successful than traditional information campaigns in several domains.

Risk communication for radon might therefore most profitably focus on framing simpler, easier, longer-lasting protective responses and communicating this information through preexisting social networks and institutions. However, there are severe limitations to a communication-only approach. First, there are practical limits on any communication effort: not everyone will be reached and not everyone will be persuaded to act appropriately. Second, there are cognitive limits on people's ability to judge low-probability risks, and highly accurate judgments and precisely appropriate responses would be difficult to achieve without regulation. Third, there are attentional limits: it may prove difficult to encourage busy people who have many other concerns and who face many hazards in addition to radon to maintain interest and concern during the long process of testing and mitigation. Finally, there are limits to our ability to frame problems and solutions in real-life contexts. In conclusion, consistent both with the available literature and with the new research presented here, such purely voluntary programs alone are likely to be ineffective for promoting effective radon mitigation. However, risk information and awareness remains a necessary component in the application of either incentives or regulation.

5.3. Incentives

Incentive programs have the general advantages of giving policy makers a more direct influence on the radon problem than an information and awareness campaign. One program might involve government subsidized testing and/or mitigation services. This strategy can defer or eliminate costs for low income homeowners or owners in areas with exceptionally high radon levels. The disadvantage of this strategy is its narrow focus and potential cost. Moreover, it raises questions, from a legal standpoint, of government liability whenever it results in damage to a home or building, or fails to reduce radon levels.

Another possible strategy would be a system of tax credits such as those used to encourage the use of solar energy in the late 1970's. These might include income tax credits for radon testing and mitigation. Radon mitigation work might also be exempted from property tax assessment, or sales tax rebates might be given on radon remediation related purchases. Also included in this category could be government sponsored low-interest or interest-free loans for mitigation.

There are advantages and disadvantages to these incentive strategies. Tax credits or tax deductions are primarily options offering equitable financial relief to home purchasers who were probably not aware whether the building or home they bought had a radon problem. On the other hand, tax relief limits collectable government revenues, and it distributes some of the cost of mitigation to people who do not have a radon problem.

An example of a tax credit approach is the Energy Tax Act of 1978 which amended the U.S. tax code to give tax credits for energy conservation and renewable energy source expenditures. For energy conservation this allowed a deduction of 15% per year (on expenditures up to $2000) and for renewable energy a deduction of 30% on the first $2000, and 20% on purchases between $2000 and $10,000 per year. At the same time 17 states passed legislation to exempt solar energy installations from property tax assessment. While there is little data on the effectiveness of individual state efforts, results on the federal tax credit program are available (Carpenter et al., 1981). It was found that while 90% of the homeowners were familiar with the tax credits, only 30% took advantage of them, and only 1% would not have made the improvements without tax credits. This includes both the conservation and the renewable resource credits. If one disaggregates these statistics it appears that the conservation tax credit has had little effect while the renewable energy credit has had a positive effect on the demand for solar space and water heating. One explanation for the weak showing of energy conservation credits relative to the solar energy credit might be that solar energy equipment appears to be very high profile and "high tech," while energy conservation measures (which are often more cost effective) are not. That is, many people were drawn to solar equipment because of its novelty. Conservation measures, on the other hand, are somewhat "run of the mill" (the neighbors are more impressed with solar panels than new window caulking). Therefore, we would expect this type of credit to increase the use of high-tech,

high-visibility mitigation techniques at the expense of more simple, inexpensive methods.

Low-interest and interest-free loans for mitigation also distribute costs to society, but they are potentially costly for the government. They may also encourage "gold plated" mitigation efforts and it may also be difficult to ensure that loan money is expended on actual radon mitigation. Further, these loans may not be accessible to low income homeowners. Economic incentives alone may result in very high direct costs to government with no guarantee that those costs will necessarily produce the intended result. For this reason incentives by themselves are not, from an economic standpoint, well suited to the present radon problem. Finally, we must seriously question whether or not these incentives are worth the cost unless they are used in concert with other programs (i.e., information or regulation).

5.4. Regulation

In some respects the radon problem, in a traditional sense, is difficult to regulate. If standards for acceptable radon levels were mandated it would be up to the government to police these standards, which would be a very costly process. Further, there is an equity issue in imposing standards which make individuals bear mitigation costs, for a substance which occurs naturally but unevenly.

Sweden has enacted the most ambitious regulatory approach to radon so far. Based on health studies, the national government set radon exposure standards in 1980 for radon concentrations within the home and required all homes above a certain level to mitigate. New

buildings were also required to meet standards in specified building codes. The national government had the legal power to condemn property or withhold necessary permits to those who did not comply. Despite such measures, Swedens' programs have met with little success.

Most of the responsibilities for promoting and monitoring testing and mitigation practices were decentralized to the municipal governments, which often had limited resources to devote to the problem. Little in the way of information was provided to homeowners who often received only a single-page list of mitigation alternatives as guidance. The Swedish government relied heavily upon individual voluntary testing and did little to motivate homeowners to test and mitigate.

With the establishment of national standards in 1980, Sweden had hoped to have mitigated most of the homes with high radon concentrations by now. However, their standards have met with little more compliance than EPA's voluntary action levels. As a result, Sweden's regulatory solution to the radon problem (which did not commit the necessary resources to enforcement) cannot be viewed as a success.

In our view, a better regulatory strategy would be to focus on action at the time of home or property sales. Such policies include mandatory disclosure of radon based on testing at time of sale or a standard applied at time of home sale. In addition to sales, other real estate regulatory strategies may be applied during leasing, home or building financing, building permit issuance, and inspection. Also, mandatory testing and mitigation of public buildings would, though

costly, reduce risk to public employees, and increase citizen confidence in government concern about radon, which in turn might increase private action.

A final suggested regulatory strategy is the development of model building codes for radon. Such codes are usually quickly adopted nationwide and would focus attention on the radon issue.

Among these options, the most appealing from our perspective is mandatory testing and disclosure at time of home sale. However, this approach must be combined with an information and awareness strategy also applied at time of home sale. We discuss this approach below.

5.5. Recommendation

This study has attempted to integrate three often disparate viewpoints - psychology, economics, and law -- within the context of addressing radon pollution. Based on the results we have obtained, we believe it is possible to combine these three disciplines to devise an effective strategy to address radon contamination in homes.

From a psychological perspective the main policy question is under what circumstances (if any) will people respond to warnings about radon. This study has shown that general information campaigns, when used alone, fail to accomplish radon reduction but that radon information provided at a key point in time, during the home sale transaction, gets the attention necessary to mitigate radon levels. Study results have also indicated that social diffusion of radon

information through, for example, realtors, contractors, and lenders, may be effective.

From an economic perspective, we have determined that general information campaigns alone do not appear to be cost effective. Economic incentives, on the other hand, have worked to encourage self-protective behavior but require consumers to be aware of the problem; in order to be effective, the incentives must be founded on information and awareness. Additionally, incentive programs must be carefully designed to avoid inefficiency or bias. Of course, the potential cost to the federal government is a major problem with incentives. Regulations can be very effective in motivating self-protective behavior, but must be carefully designed to avoid inefficiency and excessive cost.

From a legal perspective, incentives or regulation may provide an avenue to address the radon problem. As pointed out above, incentives can be costly and inefficient. It also may be difficult for the federal government to "police" incentives such as tax credits to ensure that they are put to their intended use. General regulatory strategies can suffer the same defects as incentive strategies. Nevertheless, our research suggests that effective regulations can be formulated by using the results of this study to design a regulatory strategy aimed at the home sale transaction. This strategy would require mandatory disclosure of radon level at time of home sale.

A home sales transaction strategy has certain drawbacks. First, it cannot address all radon contamination because it does not cover all dwelling units. For example, people who rent rather than own would not be affected by this strategy, although the owners of their dwellings

could be. Second, it is a relatively slow approach. Because only about 5% of all homes are sold each year it might take as long as 14 years to reach one half of all the currently existing homes. Third, it may be inequitable, although this is mostly due to the nature of the radon hazard. For example, its costs may fall hardest on the current owner/seller of the home who may be required to test and mitigate a condition that he did not create nor to which he contributed.

The home sale transaction regulatory strategy exploits a key event - the decision to purchase a home - to focus the attention of the home sale participants (e.g., buyer, seller, mortgage banker, realtor) on the potential health effects of radon contamination. During the home sales transactions, buyers and sellers are focused on the condition of the home. Buyers are anxious to learn as much as possible about the property. Sellers are likely to commit resources to correct any perceived defects.

The home sales transaction strategy requires that before the closing, radon tests be conducted, and their results obtained and disclosed, to all participants in the home sale transaction. It takes advantage of the psychological principles outlined above by providing information about radon levels in a timely fashion so that protective behavior is framed as part of a high profile, single decision that covers a long time span. It also uses existing channels of social communication to disperse information about radon by involving mortgage bankers and realtors in disseminating radon information.

The home sales transaction strategy also is economically efficient. Because the burdens of testing, disclosure, and mitigation are imposed upon the participants to the home sale transaction, the

federal government will not be forced to provide testing services or offset costs of remediation. Since the buyer, realtor, and mortgage banker have a strong self-interest in learning about radon, the strategy is to a large extent self-policing. Additionally, because the strategy does not require mitigation, it will allow the buyer and seller to negotiate for remediation of radon pollution, if necessary. Evidence suggests that the result of such negotiations will almost always be to remediate rather than compensate the buyer for accepting the risk. Thus, free market economic forces shape the ultimate resolution of the radon problem.

In order to implement this strategy, the Congress must enact legislation empowering a federal agency such as the Environmental Protection Agency to promulgate regulations requiring radon testing and disclosure of test results during the home sale transaction. Some of the legal impediments to such potential legislation are reviewed in Chapter 4 and Appendix IV. Traditionally, the federal government has not intruded into home sale transactions, although it has enacted at least one law requiring disclosure of certain closing costs in home sales financed by "federally related mortgages."

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Appendix I

Facsimile Survey for the Washington, D. C. Area Campaign

I. THE ISSUES

We would like to find out if your Air Chek radon test has been helpful to you and your family. Please answer all questions for the home you tested.

Q-1 Why did you decide to test your home for radon? (Circle all that apply)

	<4	4<20	20<50	>50
1. PRICE OF TEST KIT	38.27	43.55	38.64	40.65
2. NEIGHBORS WERE TESTING THEIR HOME	4.59	5.38	10.80	14.19
3. CONCERN ABOUT FAMILY'S HEALTH	80.10	76.88	77.27	78.71
4. WANT TO SELL HOME SOON	1.53	2.69	2.27	2.58
5. RADIO, TV, MAGAZINE, OR NEWSPAPER STORY	69.90	70.43	65.91	63.87
6. WANTED TO CHECK HOUSE BEFORE BUYING IT	1.02	0.54	0.00	0.65

Q-2 Have you ever: (circle answer for all that apply)

		NEVER	ONCE OR TWICE	MANY TIMES
1. Received an insert in your utility bill concerning radon?	<4	72.47	27.53	0.00
	4<20	70.30	27.88	1.82
	20<40	73.08	26.92	0.00
	>50	73.29	26.03	0.68
		NEVER	**ONCE OR TWICE**	**MANY TIMES**
2. Called a radon 800 number hotline?	<4	94.65	4.81	0.53
	4<20	89.33	10.67	0.00
	20<50	80.95	17.86	1.19
	>50	83.01	16.34	0.65
		NEVER	**ONCE OR TWICE**	**MANY TIMES**
3. Heard a public service announcement about radon on the radio?	<4	22.92	38.54	38.54
	4<20	26.82	34.08	39.11
	20<50	27.49	32.16	40.35
	>50	31.58	39.47	28.95
		NEVER	**ONCE OR TWICE**	**MANY TIMES**
4. Seen a public service announcement about radon on television?	<4	12.57	28.80	58.64
	4<20	9.78	32.61	57.61
	20<50	13.37	33.72	52.91
	>50	15.69	28.10	56.21
		NEVER	**ONCE OR TWICE**	**MANY TIMES**
5. Read an article about radon in a newspaper?	<4	4.10	43.59	52.31
	4<20	3.89	38.33	57.78
	20<50	5.26	38.60	56.14
	>50	2.63	42.11	55.26
		NEVER	**ONCE OR TWICE**	**MANY TIMES**
6. Attended a community group presentation or meeting on radon?	<4	96.28	3.72	0.00
	4<20	94.38	5.06	0.56
	20<50	91.18	7.65	1.18
	>50	94.08	3.95	1.97
		NEVER	**ONCE OR TWICE**	**MANY TIMES**
7. Seen a TV news story or documentary program on radon?	<4	11.34	52.58	36.08
	4<20	11.96	52.17	35.87
	20<50	7.51	54.91	37.57
	>50	10.46	52.94	36.60

8. Seen a radon poster or brochure in supermarkets or other public places?

	NEVER	ONCE OR TWICE	MANY TIMES
<4	17.62	41.97	40.41
4<20	12.50	46.20	41.30
20<50	23.67	43.20	33.14
>50	20.13	54.55	25.32

Q-3 When did you first hear about the radon problem? (circle number)

	<4	4<20	20<50	>50
1. LESS THAN 6 MONTHS AGO	0.00	1.09	0.57	1.29
2. 6 MONTHS TO 1 YEAR AGO	39.58	30.43	34.09	29.03
3. 1 TO 3 YEARS AGO	52.60	61.41	60.23	65.16
4. MORE THAN 3 YEARS AGO	7.81	7.07	4.55	4.52

Q-4 How often have you discussed radon with: (circle answer for all that apply)

1. A family member?

	NEVER	ONCE OR TWICE	MANY TIMES
<4	5.29	48.15	46.56
4<20	2.19	42.62	55.19
20<40	1.14	37.14	61.71
>50	0.67	28.00	71.33

2. A friend or neighbor?

	NEVER	ONCE OR TWICE	MANY TIMES
<4	12.09	64.84	23.08
4<20	9.47	66.27	24.26
20<40	6.59	59.28	34.13
>50	10.88	56.46	32.63

3. A government employee?

	NEVER	ONCE OR TWICE	MANY TIMES
<4	77.78	18.52	3.70
4<20	75.00	19.23	5.77
20<40	71.33	20.00	8.67
>50	69.01	25.35	5.63

4. A doctor?

	NEVER	ONCE OR TWICE	MANY TIMES
<4	96.82	1.91	1.27
4<20	94.16	4.55	1.30
20<40	94.67	4.00	1.33
>50	91.30	8.70	0.00

5. A real estate agent?

	NEVER	ONCE OR TWICE	MANY TIMES
<4	85.00	11.88	3.13
4<20	82.28	16.46	1.27
20<40	82.67	16.67	0.67
>50	80.58	15.83	3.60

6. A building contractor?

	NEVER	ONCE OR TWICE	MANY TIMES
<4	94.38	4.38	1.25
4<20	87.26	10.83	1.91
20<40	87.42	11.26	1.32
>50	82.73	14.39	2.88

7. Other (Please specify) ___100% at __<4_____

Q-5 How useful were your Air Chek test results in your evaluation of radon levels in your home? (circle number)

NOT AT ALL EXTREMELY

1 2 3 4 5 6 7

	mean	std. dev.
< 4	5.81	1.29
4<20	5.10	1.54
20<50	5.19	1.47
>50	5.43	1.70

II. ABOUT YOUR RADON TEST

Q-6 About when did you first test your home for radon?

_____MONTH _____YEAR

	mode
< 4	1988
4<20	1988
20<50	1988
>50	1988

Q-7 How many radon test kits did you use in your initial testing for radon?

_____ KITS

	mean	std.dev.
< 4	1.26	0.60
4<20	1.34	0.62
20<50	1.51	0.90
>50	1.55	0.74

Q-8 In which area of your home did you have the highest radon level?

	<4	4<20	20<50	>50
_____basement/lower level	86.43	89.53	96.49	97.87
bedroom	3.57	2.91	0.00	0.00
living room	5.71	3.49	2.34	1.42
kitchen/dining room	1.43	1.16	0.00	0.00
hallway	1.43	1.16	0.00	0.00
other	1.43	1.74	1.17	0.71

Q-9 What were the test results for this area?

_____ PICOCURIES PER LITER

Q-10 Do you think your home has a radon problem? (circle number)

	<4	4<20	20<50	>50
1. NO → **Please skip to Question 12.**	96.05	60.00	25.66	22.79
2. YES	3.95	40.00	74.34	77.21

Q-11 When do you plan to take action to fix the radon problem? (circle number)

	<4	4<20	20<50	>50
1. NO ACTION REQUIRED	57.89	17.19	3.20	5.41
2. ACTION HAS BEEN TAKEN	10.53	17.19	46.40	56.76
3. SEVERAL WEEKS	0.00	12.50	16.00	6.31
4. SEVERAL MONTHS	21.05	34.38	28.80	22.52
5. SEVERAL YEARS	10.53	18.75	5.60	9.01

Q-12 How serious a health risk do you feel radon is to you and your family? (circle number)

LOW RISK HIGH RISK

1 2 3 4 5 6 7

	mean	std.dev.
<4	2.76	2.00
4<20	2.74	1.59
20<50	3.87	1.80
>50	4.28	1.94

Q-13 How confident are you that the test results sent to you accurately measure actual radon exposure in your home? (circle number)

NOT AT ALL CONFIDENT VERY CONFIDENT

1 2 3 4 5 6 7

	mean	std.dev.
<4	5.09	1.42
4<20	4.44	1.46
20<50	4.31	1.67
>50	4.58	1.75

Q-14 What information did you receive with your test results? (circle number for all that apply)

	<4	4<20	20<50	>50
1. LETTER FROM AIR CHEK AND A SECOND TEST KIT	8.67	9.68	7.34	58.06
2. AIR CHEK'S CITIZENS' GUIDE TO RADON PAMPHLET	65.31	73.66	69.49	56.77
3. U.S. ENVIRONMENTAL PROTECTION AGENCY'S RADON REDUCTION METHODS PAMPHLET	17.86	21.51	54.80	47.10
4. A SECOND TEST KIT	1.53	1.61	2.26	18.71
5. OTHER (Please specify)	8.67	5.38	2.26	3.90

Q-15 About how much of this information did you read? (circle number)

READ NONE — READ ALL — DIDN'T RECEIVE INFORMATION

1 2 3 4 5 6 7 99

	mean	std.dev.
<4	6.24	1.39
4<20	6.19	1.51
20<50	6.22	1.34
>50	6.45	1.03

Q-16 Do you still have any of this information? (circle number)

	<4	4<20	20<50	>50
1. NO	31.55	23.56	19.54	20.39
2. YES	68.45	76.44	80.46	79.61

Q-17 How well did the information sent with your test results answer your questions concerning radon? (circle number)

VERY POORLY — VERY WELL

1 2 3 4 5 6 7

	mean	std.dev.
<4	5.48	1.44
4<20	5.00	1.58
20<50	5.18	1.38
>50	5.05	1.56

Q-18 Please circle all numbers that describe anything you have done to find out more about radon.

	<4	4<20	20<50	>50
1. CALLED OR WROTE AIR CHEK	6.04	3.95	5.29	12.00
2. CALLED OR WROTE THE U.S. ENVIRONMENTAL PROTECTION AGENCY	9.89	12.43	17.65	22.00
3. CALLED OR WROTE LOCAL OR STATE PUBLIC HEALTH AGENCIES	6.59	11.86	19.41	30.00
4. CONTACTED A LOCAL RADON REDUCTION CONTRACTOR	1.10	3.39	17.65	20.67
5. CONTACTED A TESTING CONTRACTOR OTHER THAN AIR CHEK	3.30	3.95	16.47	17.33
6. OTHER (Please specify) _____	14.29	18.08	12.94	9.33

Q-19 How difficult has it been to get information on radon reduction? (circle number)

DIFFICULT EASY

1 2 3 4 5 6 7

	mean	std.dev.
<4	5.00	1.54
4<20	4.72	1.58
20<50	5.05	1.67
>50	4.79	1.84

Q-20 Have you performed a second or follow-up radon test since receiving the results of your first test? (circle number)

PLEASE EXPLAIN YOUR REASON IN THIS BOX

1. NO →

92.31

Please skip to Question 25.

2. YES →

7.10

Q-21 About when did you retest your residence for radon?

_____MONTH _____YEAR Mode (all levels): 1988

Q-22 How many test kits did you use?

_____ KITS

	mean	std. dev.
<4	1.92	2.12
4<20	1.73	1.26
20<50	1.75	0.93
>50	1.68	1.04

Q-23 In which area of your home did you have the highest radon level in the retest?

	<4	4<20	20<50	>50
basement/lower level	92.86	82.50	84.13	94.32
bedroom	0.00	5.00	4.76	0.00
living room	7.14	7.50	6.35	1.14
kitchen/ dining room	0.00	2.50	0.00	0.00
hallway	0.00	0.00	1.59	0.00
other	0.00	2.50	3.17	4.55

Q-24 What were the test results for this area?

_____ PICOCURIES PER LITER

		<4	4<20	20<50	>50
	<4	57.14	15.38	13.79	13.33
new	4<20	42.86	82.05	36.21	21.33
levels:	20<50	0.00	2.56	44.83	26.67
	>50	0.00	0.00	5.17	38.67

Q-25 Have you moved from the home to which this survey was originally sent?

(circle number)

1. NO	97.41	97.28	98.29	96.73
2. YES →	2.59	2.72	1.71	3.27

Q-26 Were the results of your radon test part of the reason for your move? (circle number)

	<4	4<20	20<50	>50
1. NO	93.33	100.0	100.0	100.0
2. YES	6.67	0.00	0.00	0.00

Q-27 Have you taken action to reduce radon levels in the home which you tested? (circle number)

	<4	4<20	20<50	>50
1. YES →	2.73	14.29	41.52	48.63

Please continue with Section III below.

2. NO →	97.27	85.71	58.48	51.37

Q-28 What are your future plans with respect to radon in this home?

(Circle all that apply)

	<4	4<20	20<50	>50
1. NO FUTURE PLANS	65.82	28.49	14.12	14.84
2. FURTHER TESTING → WHEN? ___	25.64	39.78	31.61	25.81
3. SELL HOME → WHEN? ___	2.05	1.08	1.14	2.58
4. TAKE ACTION TO REDUCE RADON AT LATER DATE → WHEN? ___	2.05	11.83	15.43	16.13
→ I PLAN TO SPEND ABOUT $_____ TO REDUCE RADON.				
5. OTHER (Please specify) _____	1.53	2.70	3.41	1.29

Please skip the next section and continue with Section IV on page 9.

III. RADON REDUCTION IN YOUR HOME

Q-29 Why did you attempt to reduce radon levels in your home? (circle all that apply)

	<4	4<20	20<50	>50
1. CONCERN ABOUT FAMILY'S HEALTH	11.73	23.66	44.07	52.90
2. NEIGHBORS WERE UNDERTAKING RADON REDUCTION	0.00	0.00	2.26	4.52
3. REDUCTION WAS SUGGESTED WITH MY TEST RESULTS	1.02	6.45	25.42	30.32
4. REDUCTION WAS SUGGESTED AS PART OF THE SALE OF THE HOUSE	0.00	0.00	0.00	1.29
5. OTHER (Please specify) _____	1.02	1.62	2.26	1.29

Q-30 About when did you begin to take action to reduce radon levels in your home?

_____MONTH _____YEAR

YEAR		mode MONTH
<4	1988	2
4<20	1988	5
20<50	1988	5
>50	1988	6

Q-31 About when did you or will you complete your solution to your radon problem?

_____MONTH _____YEAR

YEAR		mode MONTH
<4	1988	3
4<20	1988	12
20<50	1988	12
>50	1988	12

Q-32 Which of the following have you done to reduce radon levels in your home? (circle all that apply)

	<4	4<20	20<50	>50
1. Opened windows and doors more often (natural ventilation)	10.71	21.15	28.25	35.48
2. Installed fans (active ventilation)	4.59	4.30	12.43	12.26
3. Sealed cracks and or/foundation joints	3.06	8.60	31.64	30.32
4. Sealed sump holes and/or entry points in plumbing system	0.51	6.99	24.86	28.39
5. Sealed or paved dirt crawl spaces	0.51	1.61	5.08	6.45
6. Painted walls and/or floors	2.55	3.23	10.17	9.68
7. Installed air cleaner/filter	1.02	2.15	1.69	4.52
8. Installed sub-slab ventilation system	0.00	1.08	9.04	16.77
9. Installed basement wall suction system	0.00	0.00	3.39	2.58
10. Installed heat recovery ventilation system	0.00	0.00	0.00	0.00
11. Installed basement pressurization system	0.00	0.00	0.00	0.00
12. Installed block-wall pressurization system	0.51	0.00	0.00	0.00
13. Ventilated crawl space	0.51	2.15	5.08	3.23
14. Contractor did something, but I'm not sure what	0.00	0.00	0.00	0.00
15. Other ⟶ (Please specify) _____	0.00	0.00	1.13	1.29

Q-33 Who performed these radon reduction measures on your home? (circle all that apply)

	<4	4<20	20<50	>50

1. DID THE WORK OURSELVES
2. LANDLORD
3. PRIVATE CONTRACTOR
4. OTHER

Q-34 How difficult was it to find a trustworthy radon reduction contractor? (circle number)

NOT DIFFICULT — VERY DIFFICULT

1 2 3 4 5 6 7

	mean	std. dev.
<4	5.5	2.12
4<20	4.24	2.71
20<50	3.92	2.30
>50	3.30	2.41

Q-35 Did you work with a radon reduction contractor who was certified or endorsed by the U.S. Environmental Protection Agency or a state or local government agency? (circle number)

1. NO
2. YES
3. DON'T KNOW

Q-36 How important was it that your radon reduction contractor was certified? (circle number)

NOT IMPORTANT — VERY IMPORTANT

1 2 3 4 5 6 7

	mean	std. dev.
<4	5.00	0.00
4<20	5.50	2.25
20<50	5.59	2.06
>50	6.60	0.78

Q-37 How did you determine which radon reduction methods to use? (circle all that apply)

		≤4	4<20	20<50	>50
1.	INFORMATIONAL MATERIAL FROM AIR CHEK	6.67	11.83	28.25	27.74
2.	INFORMATIONAL MATERIAL FROM U.S. ENVIRONMENTAL PROTECTION AGENCY	3.08	9.14	24.86	27.10
3.	A RADON REDUCTION CONTRACTOR	0.51	2.15	12.43	16.77
4.	NEWSPAPER AND MAGAZINE ARTICLES	4.62	10.22	19.21	21.29
5.	RADIO OR TV FEATURES	4.10	8.06	16.38	11.61
6.	REAL ESTATE AGENT	0.00	0.00	2.26	0.00
7.	FRIENDS OR NEIGHBORS	0.00	1.08	6.78	3.87
8.	OTHER (Please specify) _____	(local EPA) 0.00	1.63	2.26	1.96

Q-38 About how much have you spent on radon reduction?

INSTALLATION COST

$_____

	mean	std. dev.
≤4	115.55	227.98
4<20	319.21	1029.02
20<50	294.43	381.81
>50	344.83	395.43

OPERATING AND MAINTENANCE

$_____PER YEAR

	mean	std.dev.
≤4	43.85	78.06
4<20	22.14	44.07
20<50	17.28	29.57
>50	23.88	25.67

Q-39 How much do you feel these actions have reduced your risk from radon? (circle number)

NOT AT ALL VERY MUCH

1 2 3 4 5 6 7

	mean	std.dev.
≤4	4.00	1.73
4<20	4.63	1.51
20<50	4.78	1.79
>50	5.07	1.87

Q-40 Have you had your home retested for radon since completing your radon reduction efforts?

	<4	4<20	20<50	>50
1. NO →	92.31	84.21	68.35	59.76

Please skip to Question 44 on page 9.

2. YES →	7.69	15.79	31.65	40.24

Q-41 About when did you again test this residence for radon?

_____ MONTH _____YEAR

	MODE year	MODE month
<4	1988	6
4<20	1988	4
20<50	1988	4
>50	1988	5

Q-42 In which area of your home did you have the highest radon level?

	<4	4<20	20<50	>50
basement/lower level	100.0	83.33	95.65	90.63
bedroom	0.00	0.00	0.00	3.13
living room	0.00	0.00	4.35	3.13
other	0.00	16.67	0.00	3.13

Q-43 What is the new level in this area of your home?

_____ PICOCURIES PER LITER

		<4	4<20	20<50	>50
new levels:	<4	50.00	28.57	30.43	67.74
	4<20	50.00	71.43	56.52	25.81
	20<50	0.00	0.00	13.04	6.43
	>50	0.00	0.00	0.00	0.00

Q-44 What are your future plans for action with respect to radon?

	<4	4<20	20<50	>50
1. NO FUTURE PLANS → **Please skip to Question 46.**	30.61	22.58	18.64	16.13
2. FOLLOW UP TESTING → WHEN? _____	11.22	24.73	32.20	38.06
3. BEGIN FURTHER REDUCTION → WHEN? _____	0.00	1.61	7.34	11.61

Q-45 How much do you plan to spend on further radon reduction? (circle number)

	<4	4≤20	20<50	>50
1. $0 - $99	85.71	75.00	49.09	53.73
2. $100 - $199	0.00	15.00	20.00	8.96
3. $200 - $499	9.52	5.00	12.73	20.90
4. $500 - $999	4.76	5.00	10.91	13.43
5. $1,000 - $1,999	0.00	0.00	7.27	2.99
6. $2,000 - $2,999	0.00	0.00	0.00	0.00
7. $3,000 - $4,999	0.00	0.00	0.00	0.00
8. MORE THAN $5,000	0.00	0.00	0.00	0.00

IV. ABOUT YOU

Q-46 What is your sex?

	<4	4≤20	20<50	>50
1. FEMALE	39.06	35.56	29.14	30.92
2. MALE	60.94	64.44	70.86	69.80

Q-47 What is your age: _____ YEARS

	mean	std.dev.
<4	47.00	13.90
4≤20	48.44	13.41
20<50	45.13	12.15
>50	43.24	11.61

Q-48 Including yourself, how many members in your household are in each age group

	(MEANS)			
	<4	4≤20	20<50	>50
____ UNDER 18 YEARS OF AGE	1.63	1.62	1.74	1.89
____ 18-64	2.07	2.01	2.10	2.15
____ 65 AND OVER	1.28	1.39	1.04	1.05

Q-49 Are you presently:

	<4	4≤20	20<50	>50
1. EMPLOYED	56.25	57.78	71.75	73.68
2. UNEMPLOYED	1.04	2.78	0.56	1.97
3. RETIRED	22.92	22.22	12.43	10.53
4. FULL TIME HOMEMAKER	11.98	11.11	7.91	7.89
5. STUDENT	1.56	2.22	1.13	0.00
6. EMPLOYED PART-TIME	5.21	3.33	5.08	3.95
7. OTHER (Please specify)	1.04	0.56	1.13	1.97

Q-50 Do you own this residence?

	<4	4≤20	20<50	>50
1. NO	6.32	5.49	5.17	2.63
2. YES	93.68	94.51	94.83	97.37

Q-51 What type of residence is this? (circle number)

	<4	4<20	20<50	>50
1. SINGLE FAMILY DETACHED HOME	78.24	94.54	95.45	97.40
2. MOBILE HOME OR HOUSE TRAILER	0.00	0.00	0.00	0.00
3. DUPLEX, TRIPLEX OR FOURPLEX	3.22	0.55	0.57	0.65
4. TOWNHOUSE CONDOMINIUM OR ROWHOUSE	16.58	..4.92	3.98	1.95
5. APARTMENT (Building with five or more residences)	2.07	..0.00	0.00	0.00

Q-52 What is the zip code of the home you tested? _____

Q-53 How long have you lived in this residence?

_____ YEARS

	mean	std.dev.
<4	10.88	9.18
4<20	9.81	9.27
20<50	8.74	8.19
>50	8.65	7.63

Q-54 How much longer do you expect to live here?

_____ YEARS

	mean	std.dev.
<4	9.05	9.07
4<20	11.06	10.95
20<50	12.14	11.51
>50	14.02	13.11

Q-55 What do you think the current market value of your home is?

$_____

(IN DOLLARS)

	mean	std.dev.
<4	178,178.28	110,226.89
4<20	222,164.84	124,802.47
20<50	196,674.69	135,958.55
>50	184,696.55	93,863.32

Q-56 How much formal education have you completed? (circle number)

	<4	4<20	20<50	>50
1. NO FORMAL EDUCATION	0.00	0.00	0.00	0.00
2. SOME GRADE SCHOOL	0.00	0.56	0.00	0.65
3. COMPLETED GRADE SCHOOL	0.53	0.56	0.00	1.31
4. SOME HIGH SCHOOL	1.06	0.56	3.49	1.96
5. COMPLETED HIGH SCHOOL	7.94	11.30	8.14	15.03
6. TRADE SCHOOL	3.17	2.82	2.91	3.27
7. SOME COLLEGE	25.40	22.03	30.23	16.99
8. COMPLETED COLLEGE	19.05	20.34	19.19	26.80
9. SOME GRADUATE WORK	17.99	14.12	8.14	16.34
10. ADVANCED COLLEGE DEGREE	24.87	27.68	27.91	17.65

Q-57 Do you smoke?

	<4	4<20	20<50	>50
1. NO	88.42	86.52	82.76	90.85
2. YES	11.58	13.48	17.24	9.15

Q-58 Do you generally wear a seat belt when you travel by automobile?

	<4	4<20	20<50	>50
1. NO	10.00	9.39	4.57	6.54
2. YES	90.00	90.61	95.43	93.46

Q-59 What is your total annual household income before taxes and other deductions? (circle one)

	<4	4<20	20<50	>50
1. UNDER $9,999	2.37	0.00	0.67	0.71
2. $10,000 - 19,999	2.96	3.23	2.68	5.71
3. $20,000 - 29,999	9.47	5.81	6.04	2.14
4. $30,000 - 39,999	11.83	9.68	8.72	15.00
5. $40,000 - 49,999	17.16	11.61	22.15	17.86
6. $50,000 - 59,999	17.16	15.48	18.79	22.14
7. $60,000 - 69,999	13.61	18.06	14.77	12.86
8. $70,000 - 79,999	8.88	12.26	8.05	10.00
9. $80,000 - 89,999	3.55	10.97	4.70	6.43
10. $90,000 - 99,999	2.96	3.87	5.37	2.14
11. OVER $100,000	10.06	9.03	8.05	5.00

Is there anything we may have overlooked? Please use this space for any additional comments you would like to make concerning radon, your radon test, or radon reduction.

Your contribution to this effort is very greatly appreciated. If you would like a summary of the results, please print your name and address on the back of the return envelope (NOT on this questionnaire). We will see that you receive it.

Appendix II

Facsimile Survey for the Boulder County, Colorado Study

I. INTRODUCTION

First we'd like to ask you a few questions about your experience with radon.

Q-1 Did you first hear about the radon problem less than 6 months ago, 6 months to 1 year ago, 1 to 3 years ago, or more than 3 years ago?

N = 302		Overall	Test	No test
	1. LESS THAN 6 MONTHS AGO	5.3%	3.9%	0.8%
	2. 6 MONTHS TO 1 YEAR AGO	13.6	9.7	17.6
	3. 1 TO 3 YEARS AGO	53.0	55.8	50.0
	4. MORE THAN 3 YEARS AGO	25.5	30.5	20.3
	5. DON'T KNOW	0.7	0	1.4
	6. NEVER ----> (SKIP TO Q-38)	2.0	0	4.1

Q-2 Was this before or after you began looking for a home in Boulder County?

N = 292		Overall	Test	No test
	1. BEFORE	82.5%	85%	79.9%
	2. AFTER	17.5	15	20.1

Q-3 On a scale from 1 to 7, where 1 indicates not at all important and 7 indicates very important, how important was it to you to buy a home with a safe radon level?

N = 297

	19.5%	9.1%	11.1%	9.8%	14.5%	9.4%	26.6%	
NOT AT ALL IMPORTANT	1	2	3	4	5	6	7	VERY IMPORTANT

Overall mean = 4.25, Test mean = 5.3, No test mean = 3.1

Q-4 When looking for a new home in Boulder County, did you always, usually, sometimes, rarely, or never ask the seller or realtor if the home had been tested for radon?

N = 297

1. ALWAYS	29.0%
2. USUALLY	5.1
3. SOMETIMES	7.4
4. RARELY	7.4
5. NEVER	51.2

Q-5 When looking for a new home in Boulder County, did you ever stop pursuing your interest in a home specifically because of radon?

N = 296		
	1. YES	5.4%
	2. NO	94.6%

Q-6 Did you own and sell a home before buying your present home?

N = 297		Overall	Test	No test
	1. YES	58.9%	60.4%	57.3%
	2. NO	41.1	39.6	42.7

Q-7 Was your previous home tested for radon?

N = 173		Overall	Test	No test
	1. YES	35.3%	47.3%	22.0%
	2. NO	64.7%	52.7	78.0

II. RADON TESTING

Now we'd like to ask you some specific questions about radon and your new home.

Q-8 Was your new home tested for radon before the sale closed?

	1. YES	44.6%
N = 303	2. NO	48.8
	3. DON'T KNOW	6.6

Q-9 Was your new home tested for radon after the sale closed?

N = 163	1. YES ------> (GO TO Q-11)	11.7%
	2. NO ------> (SKIP TO Q-37)	88.3

Q-10 Did the first radon test take place before you first looked at the house, before sale negotiations began, before sale negotiations completed, or before the sale closed?

N = 136	1. BEFORE LOOKING	19.1%
	2. BEFORE NEGOTIATIONS BEGAN	13.2
	3. BEFORE NEGOTIATIONS COMPLETED	29.4
	4. BEFORE SALE CLOSED	38.2

Q-11 Who requested that the first radon test be performed?

N = 154	1. SELF OR SPOUSE	67.5%
	2. SELLER	7.8
	4. REALTOR	7.8
	5. BUILDING CONTRACTOR	3.9
	6. EMPLOYER	2.6
	7. BANKER	3.2
	8. DON'T KNOW	3.9
	9. OTHER (_____	3.2 _____)

Q-12 Who conducted the first radon test?

N = 154	1. SELF OR SPOUSE	18.2%
	2. SELLER	5.2
	3. REALTOR	3.9
	4. BUILDING CONTRACTOR	7.1
	5. TESTING FIRM	37.0
	6. DON'T KNOW	16.2
	7. OTHER(_____	12.3 _____)

Q-13 Was someone else still living in the home when the first radon test was conducted?

N = 152	1. YES	55.9%
	2. NO	44.1%

Q-14 Who payed for the first radon test?

N = 154

1.	SELF OR SPOUSE	51.3%
2.	SELLER	22.7
3.	REALTOR	2.6
4.	BUILDING CONTRACTOR	6.5
5.	DONT KNOW	9.1
6.	OTHER(_____	7.8 _____)

Q-15 Can you tell me what the highest radon level found in your new home was, measured in picocuries per liter? Remember that the EPA action level is 4 picocuries per liter.

N = 73

Mean = 4.2
Min = 0.2
Max = 18.0

_____PICOCURIES PER LITER

_____DON'T KNOW/NOT SURE

Q-16 Would you say the highest radon level found in your new home was very low, low, about average, high, or very high?

N = 81

1.	VERY LOW	32.1%
2.	LOW	32.1
3.	ABOUT AVERAGE	14.8
4.	HIGH	7.4
5.	VERY HIGH	--
6.	DONT KNOW	12.3

Q-17 Based on these test results, did you think the home had a radon problem?

N = 153

1. YES	14.4%
2. NO	86.6%

Q-18 On a scale from 1 to 7, where 1 indicates not at all confident and 7 indicates very confident, how confident are you that the test results you were told were an accurate measure of the actual radon level in the home?

N = 152

	1.3%	2.6%	4.6%	13.2%	19.7%	26.3%	31.6%	
NOT AT ALL CONFIDENT	1	2	3	4	5	6	7	VERY CONFIDENT

Mean = 5.5

Q-19 Were you given any written or printed information about radon when you were told the test results?

N = 151

1. YES	78.1%
2. NO	21.9

III. RADON MITIGATION

Q-20 Was any attempt made to reduce the radon level in your new home before the sale closed?

N = 155

1. YES	11.6%
2. NO	87.1
3. DONT KNOW	1.3

Q-21 Was any attempt made to reduce the radon level in your new home after the sale closed?

N = 137

1. YES ----------> (GO TO Q-23)	4.4%
2. NO ----------> (SKIP TO Q-30)	95.6
3. DONT KNOW ----> (SKIP TO Q-30)	

Q-22 Did the first reduction effort take place before you first looked at the home, before sale negotiations began, before sale negotiations completed, or before the sale closed?

N = 18

1. BEFORE LOOKING	22.2%
2. BEFORE NEGOTIATIONS BEGAN	5.6
3. BEFORE NEGOTIATIONS COMPLETED	27.8
4. BEFORE SALE CLOSED	44.4

Q-23 Who first requested that an attempt to reduce the radon level be made?

N = 25

1. SELF OR SPOUSE	76%
2. SELLER	8
4. REALTOR	--
5. BUILDING CONTRACTOR	4
6. EMPLOYER	--
7. BANKER	4
8. DONT KNOW	8
9. OTHER (_____ -- _____)	

Q-24 Who did the work involved in trying to reduce the radon level?

N = 25

1. SELF OR SPOUSE	12%
2. BUILDING CONTRACTOR	36
3. RADON MITIGATION FIRM	16
4. SELLER	12
5. DONT KNOW	20
6. OTHER(_____ -- _____)	

Q-25 About how much did the reduction effort cost?

mean = $522, low = $20, high = $1500

N = 14

$_____

Q-26 Who payed for it?

N = 23

1. SELF OR SPOUSE	26.1%
2. SELLER	47.8
3. REALTOR	--
4. BUILDING CONTRACTOR	8.7
5. DON'T KNOW	13.0
6. OTHER(_____	4.3 _____)

Q-27 Was a radon test conducted after the reduction effort?

N = 24

1. YES	70.8%
2. NO ----------> (SKIP TO Q-30)	20.8
3. DON'T KNOW ------> (SKIP TO Q-30)	8.3

Q-28 Can you tell me what the radon level found after the reduction effort was, measured in picocuries per liter?

N = 13
Mean = 2.8
Min = 0.5
Max = 5.0

_____PICOCURIES PER LITER

_____DON'T KNOW/NOT SURE

Q-29 Would you say the radon level found after the reduction effort was very low, low, about average, high, or very high?

N = 4

1. VERY LOW
2. LOW
3. ABOUT AVERAGE
4. HIGH
5. VERY HIGH
6. DON'T KNOW

IV. RADON TRANSACTIONS AND NEGOTIATIONS

Now we'd like to know a little bit about radon and your home-buying transactions.

Q-30 Was the selling price of the home reduced specifically because of concern about radon or because of radon test results?

N = 154

1. YES	1.3%
2. NO	98.7

Q-31 By how much was the price reduced because of radon?

N = 1

$_____

Q-32 Were any clauses concerning radon written into the final sales contract for the home?

N = 155

1. YES	39.4%
2. NO	56.8
3. DON'T KNOW	3.9

Q-33 Was the contract contingent on a radon test?

N = 61

1. YES	90.2%
2. NO	9.8%
3. DON'T KNOW	

Q-34 Did the contract state that the seller must reduce the radon level in the home if unsatisfactory?

N = 61

1. YES	52.5%
2. NO	37.7
3. DON'T KNOW	9.8

Q-35 Did the contract specify that the home must meet a specific radon level, in picocuries per liter?

N = 61

1. YES	52.5%
2. NO	36.1
3. DON'T KNOW	11.5

IF YES: Q-36 What was this level?
16 = 4.0, 1 = 20
N = 17 _____PICOCURIES PER LITER

_____DON'T KNOW

Q-37 On a scale from 1 to 7, where 1 indicates not at all serious and 7 indicates very serious, how serious a health risk do you feel radon is to you and your family right now?

N = 295

	54.9%	22.7%	12.9%	8.1%	9.8%	3.7%	7.8%	
NOT AT ALL SERIOUS	1	2	3	4	5	6	7	VERY SERIOUS

Overall mean = 2.8, Test mean = 2.8, No test mean = 2.7

V. GENERAL TRANSACTIONS AND NEGOTIATIONS

Now we'd like to ask a few general questions about your new home purchase.

Q-38 Are you the first owner of your new home?

N = 303

	Overall	Test	No test
1. YES	20.8%	18.8%	22.8%
2. NO	79.2	81.2	77.2

Q-39 How many weeks went by from the time you gave the seller your initial offer until the sale closed?

Overall mean = 6.4, Test mean = 6.3, No test mean = 6.5

N = 295 _____WEEKS

Q-40 How many offers did you make on the home before one was accepted?

Overall mean = 1.7
Test mean = 1.8
No test mean = 1.6

N = 291 _____OFFERS

Now we need to ask a few financial questions so we can determine how radon tests might affect the values of homes.

Q-41 What was the initial asking price of the seller of your new home?

N = 237 $___Mean = 123,244_____

Q-42 What was your initial offer on the home?

N = 242 $___Mean = 124,364_____

Q-43 What was the final selling price of the home?

N = 254 $___Overall mean = 118,118
Test mean = 127,180 No test mean = 108,912

Q-44 Did you deal directly with the seller or employ the services of a realtor?

N = 295		Overall	Test	No test
	1. DIRECTLY WITH SELLER	20.7%	15.8%	25.9%
	2. EMPLOYED REALTOR	79.3	84.2	74.1

Q-45 Did your realtor give you any information or advice about radon?

N = 231		Overall	Test	No test
	1. YES	43.7%	57.5%	26.9%
	2. NO	56.3	42.5	73.1

Q-46 Did your realtor agree to reduce any fees or commissions in order to close the deal?

N = 235		
	1. YES	8.9%
	2. NO	91.1%

IF YES: Q-47 How much was the reduction?

N = 7 mean = 707
$_____

VI. ABOUT THE RESPONDENT

We're almost finished. I'd now like to ask you a few final questions about yourself.

Q-48 GENDER (DO NOT ASK):

N = 301		Overall	Test	No test
	1. MALE	63.8%	61.7%	66%
	2. FEMALE	36.2	38.3	34

Q-49 What is your age?
N = 294 _____YEARS
Overall mean = 37.4, Test mean = 37.6, No test mean = 37.2

Q-50 Including yourself, how many members of your household are

N = 300 under 18 years of age? ___ 0.88 _____

between age 18 and age 65? ___ 1.93 _____

older than age 65? ___ 0.04 _____

Q-51 Are you or a member of your household employed by IBM?

N = 299		Overall	Test	No test
	1. YES	11.7%	17%	6.2%
	2. NO	88.3	83	93.8

Q-52 Are you or a member of your household employed by U. S. West?

N = 299		
	1. YES	2%
	2. NO	98%

Q-53 Do you smoke?

N = 300		Overall	Test	No test
	1. YES	11%	11%	11%
	2. NO	89	89	89

Q-54 Does any other member of your household smoke?

N = 298		Overall	Test	No test
	1. YES	11.7%	13.1%	10.3%
	2. NO	88.3	86.9	89.7

Q-55 Do you generally wear a seat belt when traveling by automobile?

N = 300		Overall	Test	No test
	1. YES	91%	94.2%	87.7%
	2. NO	9	5.8	12.3

Q-56 How much formal education have you completed?

N = 299

1. NO FORMAL EDUCATION	0.3	6. TRADE SCHOOL	1.3%
2. SOME GRADE SCHOOL	0.3	7. SOME COLLEGE	19.7
3. COMPLETED GRADE SCHOOL	--	8. COMPLETED COLLEGE	32.8
4. SOME HIGH SCHOOL	--	9. SOME GRADUATE WORK	13.0
5. COMPLETED HIGH SCHOOL	9.4%	10. ADVANCED COLLEGE DEGREE	23.1

• Median = completed college

Q-57 What is your household's total annual income before taxes and other deductions?

N = 232

1. UNDER $9,999	0.9	7. $60,000 - 69,999	9.9%
2. $10,000 - 19,999	3%	8. $70,000 - 79,999	9.1
3. $20,000 - 29,999	11.2	9. $80,000 - 89,999	4.7
4. $30,000 - 39,999	16.8	10. $90,000 - 99,999	2.6
5. $40,000 - 49,999	15.9	11. OVER $100,000	9.5
6. $50,000 - 59,999	16.4		

Median = $50,000 - 59,999

That's it, we're finished. Thank you very much for your time. Your responses will be of great value to us in evaluating public health management policies for radon.

Appendix III

Federal Laws Addressing Radon Issues

The Radon Pollution Control Act

The Radon Pollution Control Act of 1988, Pub. L. No. 100-551,102 Stat. 2755 (1988) ("RPCA" or the "Act"), to be codified as Title III of the Toxic Substances Control Act, 15 U.S.C. §§ 2601 - 2629 (1983), was passed by Congress and signed into law by the president on October 28, 1988.

The Act sets a national goal for radon in buildings; requires the United States Environmental Protection Agency to update and republish its "Citizen's Guide to Radon" (EPA, 1986a); orders EPA to develop model construction techniques and standards for controlling radon; requires EPA to develop and implement activities to assist state radon programs; and provides a grant assistance program for state radon programs. It does not provide for direct federal regulation of radon, nor does it establish national radon standards. This appendix reviews the provisions of the RPCA in detail.

Sections 301, 302, and 303

Section 301 of the RPCA declares that the long-term goal of the United States is to lower the radon levels in buildings to the same level as ambient air. Section 302 defines certain terms used in the

Act, and Section 303 requires EPA to revise and republish its Citizen's Guide to Radon. EPA must include the following information in its updated guide:

1. a series of "action levels" indicating the health risk associated with different levels of radon exposure; and

2. certain "other information," including a discussion of the increased health risk associated with the exposure of potentially sensitive populations to different levels of radon, the increased health risk associated with radon exposure and risk taking behavior, the cost and technological feasibility of reducing radon concentrations, the relationship between short-term and long-term testing techniques and measurements and action levels, and outdoor radon levels around the nation.

The Act states that the guide should be revised "[i]n order to make continuous progress toward the long term goal established in Section 301." A key piece of the RPCA's legislative history explains the intent of this section in greater detail:

> The legislative requirement to update the Citizen's Guide is principally based upon the Committee's concern that the public is interpreting radon levels as safe if they fall below EPA's action level of 4 picocuries per liter. The EPA guidance document currently advises that "follow-up measures are probably not required" if screening measurements are less than 4 picocuries per liter. In addition EPA states that "[e]xposures in this range are considered above average for residential structures." The Committee believes that many people have misinterpreted EPA's designated action level and the statements in the current Citizen's Guide as meaning that there is little or no risk from radon levels below 4 picocuries per liter. . . . [A]lthough EPA's current Citizen's Guide includes a radon risk evaluation chart and other very useful information, the Committee believes the public is relying upon EPA's 4 picocuries per liter as a health-based standard. . . . The Committee wants to encourage the public to make efforts to bring radon levels in existing homes

and buildings down as low as practicable. (H.R. 1047, 100 Cong., 2d Sess., 12-13 reprinted in 1988 U.S. Code Cong. & Admin. News 3617-18 (hereinafter House Report 1047))[20]

This passage makes it clear that Congress felt that the current Citizen's Guide and the 4 picocuries per liter standard was misleading. Congress mandated that EPA revise its guide to clarify that EPA's present "action level" entails some health risks, and to add other action levels and their related risks. In fact, House Report 1047 states that "EPA should not designate a single particular radon level as an 'action level' or 'guidance level'. . . . Rather, the Citizen's Guide should contain a series of action or guidance levels including levels below 4 picocuries per liter so that homeowners and other members of the public can evaluate the health risk at each radon level." (House Report 1047, reprinted in 1988 U.S. Code Cong. & Admin. News 3618-19 (emphasis in original))

The House Report also shows concern about "the reliability and accuracy of currently available radon testing techniques." It notes that "information [is available] suggesting that results from instantaneous or short-term radon tests may not provide a reliable and accurate indication of long-term radon levels. The Committee is concerned about people making decisions not to mitigate based on low readings from short-term radon tests....[T]he Committee expects EPA to

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[20]According to the Act's legislative history, the Senate bill was passed in lieu of the House bill after its language was amended to contain the text of the House bill. Thus, the House report, prepared by the Committee on Energy and Commerce, is essential in construing the meaning of the Act (see Allied Towing vs. Great Eastern Petroleum Corp., 642 F. Supp. 1339, 1351-52 (E.D. Vs. 1986).

consider whether the Agency should recommend that only results from long-term tests be used." (House Report 1047 at 16, reprinted in 1988 U.S. Code Cong. & Admin. News 3620)

Section 304

This section requires that EPA develop model construction standards and techniques for controlling radon levels in new buildings by June 1, 1990. To the "maximum extent possible," EPA is directed to consult with organizations involved in establishing national building standards and techniques. In developing the standards and techniques, EPA must take into account the geographic differences in construction types and materials, geology, weather and any other factors that may affect radon levels. A draft copy of these standards and techniques shall be made available to the public for review and comment.

The RPCA does not empower the Agency to issue regulations requiring adherence to the building standards, nor does it otherwise make these standards effective as a matter of law. It states merely that EPA "shall work to ensure that organizations responsible for developing national model building codes, and authorities which regulate building construction ... adopt the Agency's model standards and techniques."[21] (RPCA §304)

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[21]However, see the discussion of RPCA Section 306(d) below. This section provides that EPA shall give preference for grant assistance to states that have made "reasonable efforts" to ensure the adoption of these building standards.

In its explanation of this section, the Committee noted that EPA has collaborated with the National Association of Home Builders (NAHB) to develop a guidance document identifying construction techniques that can significantly reduce radon levels in new home construction. EPA is encouraged to continue its efforts to promote the nationwide use of construction techniques that reduce radon levels. The Committee desires that these national building standards be incorporated into model national building codes that will be adopted by state and local communities. (House Report 1047 at 16-17, reprinted in 1988 U.S. Code Cong. & Admin. News 3621)

Section 304 is not intended to require EPA to establish a performance-based standard at outdoor radon levels. The initial model construction standards and techniques and subsequent revisions are meant to "assist the public in making progress toward the national long-term goal." (House Report 1047 at 16-17, reprinted in 1988 U.S. Code Cong. & Admin. News 3621)

Section 305

Section 305, entitled "Technical Assistance to States for Radon Programs," requires EPA to develop and implement certain activities designed to assist state radon programs, including a clearinghouse for radon information, a voluntary proficiency program for rating radon measurement devices and firms and individuals that offer radon-related services, training seminars for public and private firms dealing with radon, publication of public information materials, operation of state/federal cooperative projects, demonstration of radon mitigation

methods and establishment of a national data base regarding the amounts and location of radon. It also allows EPA to provide certain discretionary assistance to states if states (or a state) request such assistance, including designing and implementing a radon survey, a public information and education program, and a program to control radon in existing and new structures.

This section also requires EPA to provide information regarding technology and methods of radon assessment and mitigation to private professional organizations. By July 1, 1989, and annually thereafter, the Agency must prepare a plan to implement this section, and submit it to Congress.

Congress authorized the appropriation of $1.5 million[22] so that EPA could establish a "proficiency rating program and training seminars" for any person desiring such services, including private firms and organizations and state and local governments. The Act requires EPA to charge for attendance at the training seminars and for participation in the proficiency rating program to "cover the operating costs of such proficiency rating program and training seminars." (RPCA §305(e)(2)) No charge will be imposed upon state or local governments. During the first three years of the rating program and seminars, the charges imposed are to be in excess of the operation costs. The excess amount collected is to be used to reimburse the General Fund of the United States Treasury for the $1.5 million

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[22]RPCA Section 305(f) states that for the purposes of carrying out Sections 303, 304, and 305, "[t]here is authorized to be appropriated an amount not to exceed [$3.0 million]."

appropriated to establish the training seminars and rating program. (RPCA §305(e)(4))

House Report 1047 states that EPA should provide "seed money" to help states initiate and establish radon programs. This financial assistance was only designed to help get state programs "off the ground" and was not intended to establish a permanent federal grant program. (House Report 1047 at 17, reprinted in 1988 U.S. Code Cong. & Admin. News at 3622)

Section 306

Section 306 covers grant assistance to states for radon programs. It provides that EPA may make a grant to a state for "the purpose of assisting the State in the development and implementation of programs for the assessment and mitigation of radon."[23] (RPCA §306(a)) Section 306 lists some of the information that must be provided in a grant application, such as a description of the seriousness and extent of radon exposure in the state, the identification of the state agency that has responsibility for radon

[23]The Act limits the federal share of the cost of radon programs in any fiscal year according to the following schedule: (a) 75% of the costs incurred by the state in the first year; (b) 60% of the costs incurred by the state in the second year; and (c) 50% of the costs incurred by the state in the third year. The state share must be provided from non-federal funds (RPCA Section 306(f)), and not more than 10% of the amount appropriated in any year may be granted to any one state. (RPCA Section 306(j)(3)) Moreover, no more than 50% of any grant shall be used to purchase radon measurement equipment and devices, and pay for costs of demonstration of radon mitigation. (RPCA Section 306(i)(2)) The costs of general overhead and program administration shall not exceed 25% of the amount of any grant. (RPCA Section 306(i)(3))

programs and which will receive the grant, a description of the radon-related activities and programs proposed by the state, and a three-year plan that outlines long-range program goals and objectives, desired federal funding, and state funding. Activities eligible for funding include radon surveys, development of public information and educational materials, implementation of programs to control radon, purchase and maintenance of analytical equipment and measurement devices, payment of general overhead and program administration costs, and development of a data storage and management system.

Starting in 1991, preference for grant assistance will be given to states that "have made reasonable efforts to ensure the adoption, by the authorities which regulate building construction within that State or political subdivisions within States, of the model construction standards and techniques for new buildings developed under section 304." The RPCA provides that EPA shall fully support eligible activities contained in state applications with the full amount of funds. If the state applications exceed the total funds available, EPA shall give priority to activities or projects based upon the seriousness and extent of the radon problem, the potential that the proposed activity or project will reduce radon levels, the potential for development of innovative radon assessment techniques or program management approaches, and any other criteria designated by EPA.

An award of federal funds is conditioned upon the state providing to the federal government all radon-related information, including survey results and risk communication studies.[24] Each state

[24]States may use federal grant funds to assist local governments in carrying out their radon programs (RPCA Section 306(g))

also must maintain a list of firms and individuals within the state that "have received a passing rating under the [EPA] proficiency rating program referred to in Section 305(a)(2)." The list shall include the rating received by each firm and shall be available to the public. (RPCA §306(h))

Congress has authorized the appropriation of $10 million for grant assistance for fiscal years 1989,1990, and 1991. This money may not be used to cover the costs of the proficiency rating program established pursuant to section 305. (RPCA §306(j)(5))

Section 307

This section requires EPA to conduct a nation-wide study of radon in schools. Based on geological data and data concerning radon in homes and other buildings, EPA must identify and compile a list of high probability radon contamination areas where schools are located. EPA is empowered to assist state agencies in carrying out this survey. It must provide to the state agency a list of high probability areas, other data about schools in the state, technical guidance, and information concerning methods of reducing radon contamination. EPA also may provide testing devices and the services of EPA's laboratories to evaluate radon test information.

On or before October 1, 1989, EPA must submit to Congress a status report regarding the school study. By October 1, 1990, EPA must submit its final report setting forth the results of the study and its recommendations. Congress has authorized up to $1 million for the purposes of carrying out Section 307, except for the "diagnostic

and remedial efforts" described in Section 307(a)(6), for which it authorized up to $500,000.

Sections 308, 309, 310, and 311

Section 308 gives EPA the discretion to enter into cooperative agreements or provide grants to establish regional radon training centers at colleges, universities, institutions of higher learning or a consortia of such institutions. EPA is directed to make grants to at least three applicants for training centers. (House Report 1047 at 19, reprinted in 1988 U.S. Code Cong. & Admin. News 3624) The regional centers are directed to develop information and provide training. RPCA sets forth certain criteria for the establishment of such regional training centers. One million dollars has been authorized for each of the fiscal years 1980, 1990, and 1991 to carry out this program.

Section 309 requires that a study of radon in federal buildings be conducted. The study shall include examination of radon contamination in nonpublic water supplied to the buildings. EPA must identify and compile a list of areas where federal buildings are located that have a high probability of radon contamination. On or before October 1, 1990, the Agency must submit to Congress a report describing the results of the study.

Section 310 authorizes EPA to issue regulations to carry out the provisions of the Act, and Section 311 states that amounts authorized to be appropriated in RPCA are in addition to amounts authorized to be appropriated under other laws for radon-related activities.

The Superfund Amendments

The 1986 Superfund Amendments and Reauthorization Act (SARA) contains two separate sections directly addressing the subject of radon gas -- Section 118 and Title IV -- and a limitation on the federal response to radon contamination in Section 104(a)(3).

In Section 118(k), SARA calls for EPA to prepare a national assessment of radon to identify the locations where the gas is found, to determine the radon levels and health risks at these locations and methods of reducing those risks, and to provide guidance and information to the public. (42 U.S.C. §9618(k)) This national assessment was to be submitted to Congress by October 1987. EPA submitted a survey of seven states in September 1988 in partial fulfillment of section 118(k). The results for tests in more states were released in October of 1989.

Section 118(k) also requires EPA to conduct a radon mitigation demonstration program to test methods and technologies of reducing or eliminating the radon threat. (42 U.S.C. §9618(k)(1)) SARA specifies that the demonstration program should be conducted in the Reading Prong area of Pennsylvania and New Jersey and other sites EPA considers appropriate. Annual reports on the status of the demonstration program are to be submitted to Congress on February 1 of each year, beginning in 1987.[25] (42 U.S.C. §9618(k)(2)(B))

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[25]SARA also added a "sense of Congress" in Section 118(m) that EPA is not required to use fully demonstrated methods when carrying out a response action at a facility listed on the National Priorities List because of radon. This provision seeks to encourage innovative or

The section addressing radon gas is found in SARA Title IV, a free standing act entitled "The Radon Gas and Indoor Air Quality Research Act of 1986." Title IV contains findings by Congress regarding the serious health risk posed by radon gas and the need for more coordination among research programs and a better information base. Title IV also establishes a research program to gather information on indoor air quality, coordinate federal, state, local, and private research, and assess appropriate federal action to mitigate the risks associated with indoor air pollution. (§403(a))

Under Title IV, Congress has required EPA to set up a research program to (a) identify, characterize, and monitor sources and levels of indoor air pollution, including radon, and including measurement of various pollutant concentrations, high-risk building types, and instruments for indoor air quality data collection; (b) study the effects of indoor air pollution and radon on human health; (c) research control technologies and other mitigation measures; (d) demonstrate methods for reducing and eliminating indoor air pollution and radon; (e) research methods of assessing the potential for radon contamination of new construction and design measures; and (f) disseminate information to assure the public availablilty of this research program. (§403(b)) Congress also set up an advisory committee composed of representatives from federal agencies, state governments, the scientific community, industry, and public interest organizations. (§403(c))

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alternative methods, particularly those involving the off-site transport and disposition of radon-contaminated material.

Title IV also specifically limits EPA's authority to conduct research, development, and related reporting, information dissemination, and coordination activities. It does not, however, limit the authority of EPA or any other agency over radon under any other authority of law. (§404) EPA submitted an implementation plan to Congress for these research activities, as required by Title IV, in 1987. A status report was planned for fall of 1989.

SARA Section 104(a)(3) also adds limitations on EPA's Section 104 response authority. The limitations regarding radon state that EPA "shall not provide for a removal or remedial action under [104] in response to a release or threat of a release -- of a naturally occurring substance in its unaltered form, or altered solely through naturally occurring processes or phenomena, from a location where it is naturally found."[26] (§104(a)(3)(A))

EPA's subsequent interpretation of this provision, a clear reading of the statute, and the legislative history support a finding that the §104(a)(3)(A) limitation on EPA's response authority includes a threat

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[26]Both the house and Senate bills to amend Superfund in 1985 contained this limitation with respect to a "naturally occurring substance," although they differed on other limitations (see H.R. 235(V), 99th Cong., 1st Sess. (1985); S. Rep. No. 11, 99th Cong., 1st Sess. (1985)). The Senate report provides detailed examples of naturally occurring substances, including concentrations of hazardous chemicals in the earth's crust, disease or contamination resulting from animal waste, and "naturally occurring (and undisturbed) radioactive rocks or soils." (S. Rep. No. 11, 99th Cong., 1st Sess., at 16) The Senate's example regarding radioactive rocks or soils would appear to include naturally occurring radon contamination in the limitation on EPA's authority. The Conference Committee adopted the Senate version of the Section 104 limitation without pertinent discussion in the Conference Report.

from radon contamination. That limitation may be overcome, however, if EPA finds that the contamination constitutes a "public health or environmental emergency" and there is no other person with the authority and capability to respond to the emergency. (§104(a)(4)) Thus, under certain circumstances radon contamination might be addressed under EPA's §104 authority. Whether radon contamination could be considered a "hazardous substance" that EPA is authorized to clean up absent an emergency with respect to §106, or that could constitute the basis for a cost recovery action under §107, are complex legal issues beyond the scope of this report.

Appendix IV

Constitutional Issues Relevant to Regulatory Strategies for Radon

This appendix addresses the potential constitutional impediments to adopting various regulatory strategies at the federal level for controlling naturally occurring radon pollution.

The Commerce Clause

The federal government has inherently limited authority and can only act on the basis of specific enumerated powers. As with most federal environmental statutes, the most probable basis for regulation of radon pollution would be the commerce clause. Even though indoor radon contamination is distinct in several ways from other environmental problems regulated under commerce clause theory, judicial interpretation has so expanded the scope of powers available to Congress that at least one commentator has noted that "no conceivable measure reasonably intended to protect the environment is beyond the reach of congressional authority."[27]

Article I, Section 8 of the Constitution provides that Congress has the power "to regulate Commerce . . . among the several states."

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[27]Philip Soper, "The Constitutional Framework of Environmental Law," in Federal Environmental Law 22 (Environmental Law Institute ed.) (1974).

(Emphasis added.) In the seminal case Gibbons v. Ogden, 22 U.S. (9 Wheat.) 1 (1824), the Supreme Court held that Congress may not regulate activities that are completely confined to a particular state, that do not affect other states, and with which it is not necessary to interfere for the purpose of executing some of the general powers of the government. Subsequent decisions have, however, significantly expanded the permissible realm of activities that Congress can regulate, to the point that activities that are essentially local in nature have been found to have an impact on interstate commerce, however theoretical, sufficient to support congressional regulation. For example, in Wickard v. Filburn, 317 U.S. 111 (1942), the Court upheld federal commodity regulations as applied to a local farmer who produced wheat exclusively for use on his own farm on the basis that the cumulative price effect of such home production on interstate commerce could be significant. The Court applied a similarly expansive analysis of "substantial economic effect on interstate commerce" in upholding the Civil Rights Act of 1964. In Katzenbach v. McClung, 379 U.S. 294 (1964), the Court reasoned that race discrimination by public facilities, such as restaurants, resulted in the sales of fewer goods, obstruction of interstate travel, and depressed general business conditions.

The distinctions between radon regulation and these other exercises of commerce clause powers are primarily (a) that radon contamination involves real property and not the traditional goods of commerce,[28] (b) radon contamination is uniquely confined to the

[28]As suggested above, however, the courts have quite generously interpreted the "article of commerce" requirement (United States v.

indoors of buildings and residences, i.e., it is not "ambient,"[29] and (c) that Congress has not traditionally "occupied the field" of indoor air pollution, real estate transactions, or building construction. On the other hand, federal regulation in other areas of longstanding state or local concern (e.g., fish and wildlife management) has steadily increased and been approved by the courts. And, the recent enactments of federal legislation (see Appendix III) encouraging research and providing assistance to states, though expressly non-regulatory, may provide a sound basis for later demonstrating the significance of the federal interest.

The most plausible theory supporting a commerce clause basis for federal regulation of radon contamination is the "effect on

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Sullivan, 332 U.S. 689, 698 (1948)) (commerce clause powers extend to articles that have completed an interstate shipment and are being held for future sales in purely local or intrastate commerce).

[29]In contrast, the commerce clause theory behind federal regulation of ambient air pollution is that ambient air connot be confined to one state's borders. As one court noted, "emitted particles themselves may be seen as themselves constituting articles moving in commerce and hence directly subject to regulation." (United States v. Bishop Processing Co., 287 F. Supp. 624, 629 (D. Md. 1968), aff'd, 423 F.2d 469 (4th Cir. 1970), cert. denied, 398 U.S. 904 (1970)) Bishop also demonstrates that an "article of commerce" need not have a commercial value, and it is irrelevant that movement of the article across state lines was not intentional. On the other hand, as mentioned above, the radon problem occurs precisely because of radon's lack of ambience, i.e., confinement to buildings. Thus, it would be difficult to argue that radon contamination itself can form a sufficient interstate basis for federal regulation under the commerce clause. One could argue, however, that even though the particles themselves are not ambient, the geological formations that create the problem are by nature interstate (i.e., deposits of phosphate, granite, and shale are not confined neatly to state borders).

interstate commerce" argument.[30] Under this approach, the courts would examine the competitive effects of the problem or the lack of federal regulation. For example, different radon testing, disclosure or mitigation standards in different states can impact on industry location, pricing of real estate, personnel relocation decisions, and individual consumption patterns. The commerce clause argument to support federal radon regulation of contracts for sales of property (i.e., disclosure, testing, or mitigation) would run as follows: although concentrations vary regionally, radon contamination is a significant nationwide problem; leaving regulation to the states could lead to inconsistent standards among the states, directly affecting interstate commerce related to real estate transactions, in building materials, and in testing and mitigation services, and indirectly affecting interstate commerce in other areas (e.g., industry relocation); and there is a significant need for federal coordination because states lack the necessary financing and technology to address the problem comprehensively.[31] In short, the commerce clause provides the

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[30]Another interesting, though relatively unused, theory that could support congressional regulation is Congress' power to approve interstate compacts. (U.S. Const., art. 1, sec. 10) "Since under the Constitution congressional approval is required for these agreements, an indirect handle is provided for imposing minimum federal environmental standards by conditioning approval of such agreements on the compatibility of the compact's terms with the federal standards." (Soper, supra note 27, at 32) Such leverage hinges, of course, on the states' own incentives to enter into such compacts, which despite the regional nature of some radon "hot spots," are probably minimal.

[31]For example, the New Jersey Department of Environmental Protection ran out of money in its efforts to mitigate radon contamination from uranium mill tailings fill in three communities in New Jersey (Galen, "Lawyer's grapple with radon issue," Nat'l L.J., July 21, 1986, at 10).

strongest "hook" for an exercise of congressional regulatory power, and such regulation would likely be upheld despite the unusually localized aspects of the radon contamination problem.

The Tenth Amendment

Under the tenth amendment to the Constitution, powers not delegated to the federal government are reserved to the states. The police powers reserved to the states include those involving public safety and public health. (See Berman v. Parker, 348 U.S. 26, 32 (1954).) Whether the tenth amendment acts as a limitation on federal power depends on the constitutional underpinning for that federal exercise. For example, if Congress can legitimately utilize its commerce power to regulate, then the tenth amendment does not constrain its actions. (United States v. Bally, 345 F. Supp. 410 (D. La.1972)) However, similar to pre-emption theory (discussed below), when Congress legislates in a field that the states have traditionally occupied, the historic police powers reserved to the states under the tenth amendment are not superceded unless that was the clear and manifest purpose of Congress. (Fouke v. Mandel, 386 F. Supp. 1341 (D. Md. 1974))

To succeed, a claim that congressional commerce power legislation is invalid under the tenth amendment must show that (a) the challenged statute regulates "states as states," (b) the federal regulation addresses matters that are indisputably attributes of state sovereignty, and (c) state compliance with the federal law would directly impair the state's ability to structure integral operations in areas of traditional governmental function. (Hodel v. Virginia Surface

Mining and Reclamation Ass'n, 452 U.S. 264, 287-88 (1981)) Despite this seemingly high standard, some federal legislation has been struck down as unconstitutional under the tenth amendment. For example, the Federal Resettlement Administration (part of the Emergency Relief Appropriation Act of 1935), which attempted to regulate and control housing and shift destitute and low-income populations, was found unconstitutional as invading the reserved powers of the states. (Township of Franklin, Somerset County, N.J. v. Tugwell, 85 F.2d 208 (D.C. Cir. 1936)) On the other hand, the Federal Emergency Price Control Act of 1942, which authorized a federal administrator to fix maximum rentals in a defense area was upheld even though rentals were considered a matter for local legislation and one not delegated to the United States. (Ritchie v. Johnson, 144 P.2d 925, 158 Kan. 103 (1944))

A more detailed analysis of the potential tenth amendment challenges to radon regulation depends on the specific regulatory strategy proposed. In general, however, such regulation would probably survive a tenth amendment challenge so long as Congress convincingly set forth its longstanding interest in the problem.

The Fifth Amendment -- Takings Clause

Intrusive regulation at both the state and federal level could be subject to challenge on the basis of the takings clause of the fifth amendment,[32] which provides that private property shall not "be taken for public use without just compensation." The takings argument most applicable to the radon regulation strategies described above would be the "diminution in value" theory. Under this theory, a seller could argue that the requirements of disclosure, testing, and/or mitigation diminish the value of the property to the extent that a taking by the government has occurred. How much diminution must occur before a court will find a taking and order compensation is a question that cannot be answered satisfactorily given the murky state of takings law, particularly without an examination of the specific

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[32]Other potential fifth amendment issues might arise under different regulatory strategies. For example, if EPA were to require testing of privately owned buildings (with attendant enforcement powers providing for physical access to property), there might be a fifth amendment search and seizure concern. But, such governmental intrusion under similar circumstances has been upheld in the face of takings attack. See State Waste Management Board v. Bruesehoff, 343 N.W.2d 292 (Minn. App. 1984) (electrical sensitivity testing conducted by the Waste Management Board in connection with selection of commercial hazardous waste disposal sites did not rise to level of a taking, given that it involved only temporary, minimal intrusion and did not substantially interfere with property rights or cause measurable decline in market values). Similarly, information and disclosure requirements may involve fifth amendment self-incrimination issues. Once again, however, disclosure of information to EPA has been upheld against this type of takings challenge (Ruckelshaus v. Monsanto Co., 467 U.S. 986 (1984)). Furthermore, extensive use of access and disclosure schemes under other environmental statutes (e.g., CERCLA), also suggests that these fifth amendment concerns are peripheral.

governmental action at issue and the alleged loss in value.[33] And, whether such federal regulation would be considered for "public use" is questionable.[34]

In the seminal case of Pennsylvania Coal v. Mahon, 260 U.S. 393 (1922), the Supreme Court held that a drastic reduction in the economic value of property triggers the need for compensation, but declined to define the point at which a regulation "goes too far." The lower courts have subsequently developed the general rules that: a taking occurs if the regulation deprives the property of all potential value or use;[35] a taking has not occurred if the owner merely is not

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[33]"[N]o single formula [for federal takings principles] is either possible or desirable. All such formulations, for example, may prove to be only extrapolations from what is basically an ethical judgment about the fairness of refusing to distribute across a broad base the costs entailed in implementing certain public programs perceived to have positive net benefits. As such, the takings clause, like the Due Process Clause and other constitutional expressions of broad, social policy may be expected to reflect changes in society in a way that allows doctrinal development to keep pace with shifting priorities in societal values." (Soper, supra note 27, at 61)

[34]Even though the general public benefits incidentally from mitigation of radon in private buildings, if the legislation placed the burden on sellers to mitigate, it arguably could be challenged as not being for public use because it creates only a private benefit to the new owner. But see Monsanto, 467 U.S. at 1014 (broadly interpreting the "public use" requirement); and National Board of Young Men's Christian Ass'ns. v. United States, 395 U.S. 85, 92 (1969) (any protection of private property also serves a broader public purpose).

[35]See, e.g., Bartlett v. Zoning Comm's Town of Old Lyme, 161 Conn. 24, 282 A.2d 907 (1971) (invalidating tidal wetlands restrictions that deprive owner complete use of property); Maine v. Johnson, 265 A.2d 711 (Me. 1970) (Maine Wetlands Act deprived plaintiff of all commercial value and constituted a taking); Morris County Land Improvement Co. v. Parsippany-Troy Hills, 40 N.J. 539, 193 A.2d 232 (1963) (invalidating meadow development zone as applied to certain wetlands). A less than confiscatory impact may be severe enough to constitute a taking if the governmental action is not

realizing a speculative investment potential or is not allowed the most profitable use of the land. As the Supreme Court recently commented, the factors a court will consider include "the character of the governmental action, its economic impact, and its interference with reasonable investment backed expectations." (Pruneyard Shopping Center v. Robbins, 447 U.S. 74, 83 (1980)) Thus, if a reasonable, economically profitable use of the land remains, a takings claim will probably not succeed.[36] As one state court commented, "there is no constitutional impediment to making a landowner personally responsible for the reasonable cost of abating hazardous conditions existing on the property." (City of Patterson v. Fargo Realty, Inc., 174 N.J. Super. 178, 415 A.2d 1210 (N.J. Super. 1980))

In addition, given that the diminution in value in the typical mitigation case would be small (relative to the value of the property),[37] a takings claim would undoubtedly fail. However, in extreme cases, for example, where mitigation costs approach the market value of the property, a seller might theoretically have a viable argument. The takings argument might also be of greater concern should EPA's safety

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sufficiently related to the legitimate governmental interest. See Nollan v. California Coastal Commisioner, 107 S. Ct. 3141 (1987).

[36]Kirby Forest Industries, Inc. v. United States, 467 U.S. 1, 15 (1984) (even substantial reduction of attractiveness of property to potential purchasers does not entitle owner to compensation under fifth amendment).

[37]Under the current working level standard, EPA estimates of mitigation costs run from $150 to $1500. GAO estimates are higher (ranging from $4300 to $10,300, not including the cost of a consultant ($4150)).

standard be set to very low levels (resulting in increased mitigation costs).

Pre-emption Issues

Under the Supremacy Clause, U.S. Const., art. VI, cl. 2, state laws must yield to federal regulation in areas where the governments have overlapping authority. Given that the tenth amendment reserves certain powers to the states, including the power to protect public health, and the extensive nature of current state regulation, an analysis of the desirability of further federal regulation should be cognizant of the political and legal issues raised by the potential for federal pre-emption of state programs. To avoid uncertainty, Congress should always make explicit in any new legislation whether it intends that state laws be preempted. Otherwise, courts and litigants will later be left the difficult and uncertain task of discerning congressional intent.[38] Principles of pre-emption may then invalidate state regulation in part or altogether, or may limit states to enforcing the safety standard set by the federal government.[39]

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[38]See Pennsylvania v. Nelson, 350 U.S. 497 (1956) (analyzing factors such as "pervasiveness" of federal scheme, "dominance" of federal interest, and whether the area has traditionally been one of state and local, rather than federal, control).

[39]See Northern State Power Co. v. Minnesota, 447 F.2d 1143 (8th Cir. 1971), aff'd, 405 U.S. 1035 (1972) (state attempt to impose radiation emission standards on a nuclear power plant stricter than those required under federal law held pre-empted by Atomic Energy Act).

With regard to radon contamination, in the absence of expressed congressional intention, the strong state interest in health and welfare, and the historical lack of interest in indoor pollution (and in private property transfers) by the federal government, would strongly support a state's argument that its laws establishing higher standards or additional requirements should not be preempted.[40] The outcome of such a challenge would, of course, once again turn on the specifics of the conflicting regulatory schemes at issue.

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[40]Soper suggests that state regulation in the environmental context enjoys a presumption of validity in the context of a pre-emption challenge (supra note 27, at 99-100): "Attempts to cope with environmental problems have led to increasing recognition of the complexity of the solutions and of the often inadequate knowledge base for providing such solutions. These facts strongly support an approach to interpretation of the Commerce Clause that preserves maximum flexibility for state experimentation in the absence of explicit contrary directions from Congress."