The Radon Mitigation Decision: Factors Influencing Homeowners

Introduction

Once people have tested their home for radon and received test results indicating that their radon level is above the Environmental Protection Agency's (EPA's) action level of 4 pCi/l, what are the factors that influence whether or not they take action to reduce their home radon level?

Understanding these factors is the first step towards developing programs that effectively motivate people to mitigate high radon levels. Social science research on radon mitigation behavior makes an important contribution to this understanding. In order to identify the factors that are related to people's mitigation actions, social scientists ask mitigators and non-mitigators questions about a variety of factors that might have influenced their decision whether or not to mitigate the high radon levels in their home.

Most of the available social science research on radon testing and mitigation behavior was conducted in the late 1980s and early 1990s. This research followed relatively soon after the discovery in the U.S. that high levels of radioactivity could be present in buildings as a result of radon gas entering through cracks in foundations and cellar walls. In many of these studies, radon mitigation is defined as taking at least one of a number of actions. Depending on the study, the options might include limiting use of the basement, keeping windows open, actively ventilating, sealing or caulking cracks and openings, painting walls or floors, or installing air cleaners, sub slab ventilation, pressurized loft/ceiling fans, solid floor sumps or suspended floor mechanical ventilation. Every study included the installation of an active system as an option, but almost all included other options as well.

In 2006, effective radon mitigation is commonly understood to include an active system of some sort, which is a permanent modification to the building and which is installed by a professional mitigation contractor. In combination with the installation of an active system, a mitigation contractor may also take passive measures, such as sealing and caulking cracks and openings.[1]

When mitigation includes a wide range of options, from behavioral changes to building modifications of varying complexity, it is possible that the factors influencing people's mitigation decisions are different than when mitigation means hiring a professional contractor to install an active system. However, it is difficult to know if this is the case, because there are so few studies in which mitigation is defined as it is in 2006. In fact, the same influential factors do often show up across studies, even then the definition of mitigation is somewhat different. To exclude the research efforts in which the definition of mitigation is broader than the current one would reduce the number of applicable studies to a very small number. Therefore, this document includes findings from studies in which mitigation is defined as including some options not currently considered effective.

Some studies reported results for several different definitions of mitigation. For example, in 1990 report prepared for the EPA, James Doyle and his co-authors defined "claimed mitigation" as including anything from opening windows to hiring a professional mitigator to install an active system. Doyle et. al. also reported on the factors that they found to be linked to "credible mitigation," which they defined as mitigation actions that cost money. Thus, behavioral changes such as opening windows were ex-

cluded from the definition of credible mitigation. When a study reported more than one set of results, based on more than one definition of mitigation, this document includes the findings for the definition of mitigation that is most similar to the one in use in 2006.

This document is divided into four parts.

Part I: Factors Influencing Mitigation Actions. This section describes the factors that show up in numerous studies as influencing decisions whether or not to mitigate.

Part II: Mitigation intentions and Action. This section describes an investigation into whether the factors leading people to decide to mitigate are the same ones that determine whether those who have decided to mitigate actually do so. If they are not, the interventions that are most effective in getting undecided people to decide to mitigate may be different than the interventions that are most effective in getting decided-to-act people to carry out their plans.

Part III: Factors Influencing Follow-Up Testing. This section reports on the results of several studies that examined the factors influencing people's decision to conduct a follow up, confirmatory test once an initial test has shown radon levels higher than 4 pCi/l in their home. As with the decision to mitigate, the consumer has an indication that there is a potentially serious health risk in their home, and they are being asked to devote effort, time and money on further action. In this case, they are taking a step to either rule out the threat or confirm it.

Part IV: Radon Testing and Mitigation During Real Estate Transactions. This section reports on an investigation into the factors that influence radon testing and mitigation during real estate transactions. The section also includes important anecdotal information provided by testing and mitigation contractors on this topic.

Part I. Factors Influencing Radon Mitigation Action

If you follow the news, you know that scientific studies are not always in agreement. Is margarine good for you or bad for you? High fiber foods lower your cholesterol. Then again, maybe they don't. Estrogen supplements have valuable benefits. But, the dangers might outweigh the benefits. The sorting, sifting and weighing of sometimes contradictory, sometimes confirming evidence is part of the process by which scientists arrive at recommendations regarding health issues. Similarly, in identifying the factors that influence radon mitigation action, it is important to look at patterns that emerge across numerous studies, rather than relying on the results from a single study. Here are some broad patterns that emerge from social science research on radon mitigation action.

Perceived Seriousness of Radon Level. The more that people perceive the radon level in their home to be dangerous or to be a serious problem, the more likely they are to mitigate.[2]

- Mitigation was related to Maine residents' memories of how serious their radon level had seemed when they first received their results (an average of 17 months prior to the survey.)[3]
- In New Jersey, an examination of six data sets on homeowner mitigation intentions and actions indicated that a homeowner's general appraisal of the seriousness or danger of his/her radon level was a particularly good predictor of mitigation intentions and actions. What contributed to these appraisals of threat? The study's authors concluded that perceived danger and problem seriousness primarily reflected beliefs about the likelihood of illness if no action were taken, and to a lesser extent, the belief that one's level was greater than that of others in the community.[4]

- In Onondaga County, New York, researchers found a significant correlation between the perceived seriousness of the radon level in respondents' homes and remediation action.[5]
- A major reason for not performing mitigation among New York State residents whose radon levels were above 4 pCi/l was, "Radon level is not that high." Fifty-eight percent of the people with home radon levels between 4 and 10 pCi/l who did not mitigate expressed this opinion. However, even at levels greater than or equal to 20 pCi/l, about 23% of the respondents who did not perform mitigation believed that radon levels in their homes were not that high.[6] In a significant number of cases in Northamptonshire, UK, people did not mitigate when a moderate level of radon was found.[7] Researchers also found that householders in the southwest of England did not mitigate just above the action level, as, in such cases, they considered action unnecessary.[8]
- In 2005, the Alabama Radon Education Program surveyed individuals who had tested their home between 2001 and 2004 and who had radon levels greater than 4 pCi/l. Twenty-eight percent of the 46 Alabama survey respondents who had not mitigated indicated that they didn't believe their level of radon was a real hazard to their health. This was the second most common reason given for not mitigating.[9]

Actual Radon Level. People are more likely to mitigate when higher levels of radon are present in their home.

- In a review published in 1992, Neil Weinstein and Peter Sandman concluded that "most studies have found a clear association between radon level and mitigation action." However, they also concluded that while mitigation usually increases with the radon level, even at high levels, there are many people who do not act.[10]
- In 1995 and 1996, the New York State Department of Health interviewed 1,113 households that had tested and found the radon level in their home to be above 4 pCi/l. The percentage of households installing a powered system to provide more ventilation or to draw radon out from the basement increased with increasing radon level, from 39% for the level of 4-10 pCi/l to 64% for the level of 50 pCi/l and above.[11]
- In southwest England, radon level was positively related to taking 'approved building actions.' 'Approved building actions' included pressurized loft/ceiling fans, solid floor sumps and suspended floor mechanical ventilation, but did not include 'Do It Yourself' actions such as increasing ventilation, sealing cracks in floors, sealing unused chimneys and placing impenetrable material to seal floors.[12]
- In New Jersey, an examination of six data sets on homeowner mitigation intentions and actions indicated that the home's radon level was one of the strongest and most consistent predictors of mitigation intentions and action. However, intentions and actions did not increase with radon level as fast as the increase in radon level itself, showing a leveling off of mitigation rates at high risk levels.

  Numerical test results influenced mitigation responses directly, not just through their effects on homeowners' appraisal of the threat. That is, the researchers were better able to predict people's mitigation intentions and actions when they took into account the home radon level as well as the homeowner's appraisal of the seriousness or danger of his/her radon level. The researchers speculate that this independent effect of radon levels was likely due almost en-

tirely to the existence of the EPA's 4 pCi/l action guideline. "The guideline served as a benchmark to which homeowners could compare their own radon levels without having to arrive at an independent judgment about the seriousness of the risk," the authors wrote. Thus, the guideline strengthened the relationship between radon level and people's mitigation response.[13]

Relationship between Perceived Risk and Actual Risk. Many studies that examine the factors influencing people's mitigation decisions look at whether people are accurately perceiving the risk they face from the radon in their home. Researchers have found that correlations between perceived and actual risk range from non-existent to moderate.

- Maine homeowners' estimates of the probability of death from their radon levels were uncorrelated with EPA risk estimates [14]
- The Department of Health of Onondaga County, New York found a moderate correlation between subjective risk and home radon level.[15]
- The author of a research review published in 1989 concluded that the correlation between subjective risk and radon level was near zero.[16]
- In New Jersey, the authors of a study encompassing six data sets on homeowner mitigation intentions and actions concluded that a variety of perceptions (perceived danger, perceived problem seriousness, beliefs about the likelihood of health effects, and anxiety) that one would expect to be closely related to the observed radon level were in fact only weakly related to the actual radon level.[17]
- The results of the New Jersey study also indicated that as their radon levels increased, homeowners were not any more likely to judge their risk to be greater relative to familiar scenarios such as smoking a pack of cigarettes per day, driving without wearing a seat belt or living near a hazardous waste site.[18]
- Sixty-two rural Iowa households with radon levels greater than or equal to 20 pCi/l completed a survey three months after they received their test results. Forty-four percent correctly identified living in a home with high radon levels (>20 pCi/l) as a greater health risk than getting 20 chest x-rays/yr (in fact, living in a home with a low yearly radon level of 1 pCi/l poses more hazard than getting 20 chest x-rays/year). Fifty-seven percent of the survey participants incorrectly selected smoking one pack of cigarettes per day as the greater health risk over living in a home with high radon levels. "These findings suggest that the majority of the participants either do not know or underestimate the health risks high radon levels pose compared to two other commonly encountered health hazards," concluded the researchers.[19]

Studies have also found that people tend to underestimate their risk. That is, they have an "optimistic bias."

- Researchers in Maine reported that the risk perceived by their survey respondents tended to understate the measured risk by orders of magnitude.[20]
- A study of 141 New Jersey homeowners with high radon levels also indicated that discrepancies between actual and perceived risk are not totally random. Researchers identified an optimistic bias in people's perception of the seriousness of radon's effects on family members. Only 52.6% of the survey sample said the health problems produced by radon would be serious or very serious. "Since the only established effect of radon is an increased risk of lung cancer, and since lung cancer is fatal in most cases, we regarded answers of "serious" or "very serious" as properly reflecting the potential

health consequences of radon," wrote the authors. Even respondents who knew that radon can cause lung cancer were reluctant to acknowledge that it would be serious if they became sick because of radon.[21]

Cost. The expense of carrying out mitigation actions is often cited by those who do not mitigate the high radon levels in their homes.[22]

- In New York State, a major reason given by those with radon levels above 4 pCi/l for not performing mitigation was that mitigation is too expensive. The results of this study also provided other evidence that the cost of mitigation was an issue for survey respondents. The researchers found that household income had a strong effect on the mitigation method selected. "The less expensive methods," said the researchers, "such as opening windows and doors or sealing or caulking cracks and openings in the basement or foundation, were used by 82% of respondents in the lowest income groups and only 25% in the highest income group. The method of installing a powered system to provide more ventilation or to draw radon out from the basement, which is relatively expensive, was used by only 18% in the lowest income group and 74% in the highest income group." This strongly suggests that the cost of mitigation was a major concern for respondents when choosing mitigation methods.[23]
- A survey conducted by the University of British Columbia measured the willingness of the public to pay for mitigation at various concentrations of household radon. The expressed willingness to pay for mitigation rose from 30% of respondents at 5pCi/l to 60% at 22piC/l. "However," the researchers wrote, "the revealed preferences (as revealed by what they had done and spent to reduce their exposure to radon) were lower, at 15% to 40%, respectively. The radon concentration would have had to exceed 30pCi/l before 50% of respondents took any action."[24]
- A survey of 10,000 respondents suggested that the overall uptake of mitigation among a sample of householders with radon levels above the action level was low, at only 10%. Reasons given for not mitigating were evenly split between those hampered by cost considerations and those believing that radon was not a hazard.[25]
- Twenty-nine percent of respondents in a Galway, Ireland survey checked off "Too expensive" as a reason for not taking mitigation action. Perceived cost was also cited as a reason for inaction by a small subset of survey respondents who were interviewed face to face.[26]
- One third to one half of those responding to various surveys in South West England gave 'high cost' as a reason for not remediating, making cost the most common reason cited by respondents for not acting.[27]
- Sixty-four individuals participated in focus group research on radon in Michigan. None of the focus group members had tested or mitigated and most knew very little about radon before the focus group sessions. "The perceived high cost of fixing a home contributed to a sense of helplessness among the participants," wrote the researchers. "Many participants thought that even $500 for radon mitigation was prohibitive and that this would interfere with their ability to do anything to decrease radon exposure."[28]
- Seventeen percent of 46 Alabama survey respondents who had not mitigated indicated that they had decided that installing a radon removal system was too expensive. This was the third most common reason given for not mitigating.[29]

- In New Jersey, the authors of the six sample study reported that people who planned to act but had not done so cited cost as an issue.[30]

Confusion about mitigation techniques

- One hundred Virginia households with radon levels above 4 pCi/l were interviewed by telephone six months to one year after they had purchased a test kit. Comments made by study participants at the end of the interview indicated that confusion about mitigation techniques contributed to the apathy about radon reduction action.[31]
- Among New Jersey residents surveyed in 1986 who were undecided or still in the planning stage (49% and 53% respectively), uncertainty about the best mitigation method was the most common reason for not mitigating. Researchers also conducted lengthy face to fact interviews with 16 survey respondents. "The desire for help in choosing remediation strategies was especially strong," the researchers wrote. "Many of the people we interviewed wanted a prescribed course of action, not an explanation of the various options available to them. Most interviewees expressed a desire to do something, but few had a clear idea of what to do. Those individuals who lacked "handyman" skills were especially confused about the course of action they should take."[32]
- Among 106 survey respondents with radon levels over 5.4 pCi/l in the Galway area of Ireland who had not mitigated, not being able to decide what to do was the most frequent reason (41%). Face to face interviews with a small subset of these survey respondents revealed that fear of exploitation and the difficulty in obtaining information on remediation were cited as reasons for inaction.[33]

Lack of Time

- Lack of time was the second most common reason for not mitigating given by New Jersey residents surveyed in 1986 who were undecided or still in the planning stage (40% and 32% respectively).[34]
- After 'high cost', which was the most common reason for not remediating, 'too busy" was one of four reasons that were equally likely to be given by survey respondents in southwest England for not taking mitigation action.[35]

Difficulty interpreting technical information

- In interviews with New Jersey residents, researchers found that the units in which radon levels are usually reported, picocuries of radiation per liter of air, were unfamiliar to interviewees. Many of the people interviewed found their test results virtually meaningless.[36]
- EPA has found that some people are confused about what the units of the test results mean, and how to interpret the seriousness of their measurement.[37]
- Focus group participants in Michigan were asked to give their impressions of a number of pamphlets about radon. None of the focus group members had tested or mitigated and most knew very little about radon before the focus group sessions. Participants said "picocuries per liter is difficult to understand. How big is a picocurie? It's not something there is a tangible idea for."[38]

Belief about affect on property value

- Fourteen interviewees in the Galway area of Ireland with radon levels above the action level were asked about perceived barriers to implementing change. The interviews revealed that the perceived effect of mitigation on the subsequent value of the property was very important. "One householder," said the re-

searchers, "who by the installation of a sub floor depressurization system had successfully reduced his radon level, felt this would benefit its sale, but a number of respondents felt that any construction work aimed at reducing their level would be evident and possibly deter potential buyers. Many would not voluntarily divulge their radon level to a potential buyer, yet, paradoxically, most would want to know the level of any property they intended to purchase."[39]

- In New Jersey, the authors of the six sample study on homeowner mitigation intentions and actions concluded that the effect of elevated radon concentrations on property values (i.e. the belief that the effects on the value of one's home would be small if radon levels were reduced) was sometimes correlated with mitigation responses, and thus may provide a potential avenue of influence.[40]
- In southwest England, researchers found that 'property pragmatism' was a strong predictor of taking 'approved building action,' which consisted of installing an active system for mitigating high radon levels.[41]

Demographic Factors. Many studies that examine the factors influencing people's mitigation decisions have explored whether demographic characteristics, such as age, sex, education, income, number of children and length of residence are linked to the likelihood that people will take mitigation action. In additions, these studies sometimes look at whether those who take other actions with the potential to affect their well being, such as wearing seatbelts or smoking, are more or less likely to mitigate high radon levels in their home.

None of the relationships between individual demographic factors and mitigation action show clear patterns, with some studies finding correlations and other studies finding that these same demographic factors and mitigation action are unrelated or only very weakly related.[42] [43] [44] [45] [46] [47] There does appear to be a pattern, however, showing that smokers are less likely to take mitigation action than non-smokers.[48]

Part II. Mitigation Intentions and Action

A significant body of research explores whether there are distinct stages in how people respond to radon and other hazards. "In particular," say researchers Neil Weinstein and Peter Sandman, "the variables that determine whether people decide to take action may not be the ones that determine whether the individuals who have decided to act actually do so."[49] If this is true in the case of radon, the interventions that are most effective in getting undecided people to decide to mitigate may be different than the interventions that are most effective in getting decided-to-act people to carry out their plans.

Weinstein and Sandman used six data sets on homeowner mitigation intentions and actions collected in the state of New Jersey to investigate whether the factors that influence intentions to mitigate are different than the ones that influence mitigation actions. Mitigations were defined as permanent home modifications. The samples consisted of New Jersey residents who had tested their homes for radon and who had volunteered to participate in a study. Five of the six samples consisted of New Jersey residents who had found high radon levels in their home and who had obtained a free follow up measurement from the Confirmatory Monitoring Program of the New Jersey Department of Environmental Protection. The sixth sample consisted of homeowners who had tested privately, but did not necessarily obtain a reading above 4pCi/l, and who may or may not have sought state government confirmation of their readings. The samples are likely to differ systematically from testers who de-

cline to participate in studies and from testers who do not seek state confirmation of their readings.[50]

A number of other researchers have also explored the factors correlated with intentions to mitigate, and their research results are also presented here where appropriate.

Intentions to Mitigate

A number of factors showed significant correlations with intentions to mitigate. Among the variables with the **strongest** associations were:

- General appraisals of the seriousness or danger of the homeowner's radon level. The Onondaga County Department of Health in New York State also found a significant relationship between perceived seriousness of a home's radon level and intention to mitigate. Their variable, Specific Concern, incorporated responses to the following questions: How much of a problem is the radon level in your home? If you don't take any action, do you think the radon in your home will eventually make you sick?[51] The UK Department of the Environment found positive correlations between a variable they called "Health Concern" and intention to mitigate.[52]
- Beliefs about the likelihood of illness if no action is taken;
- Self reported concern;
- Whether the basement radon level was above or below 4 pCi/l. Receipt of radon test results showing levels higher than 4 pCi/l was also a significant predictor of planning to reduce radon in rural Dekalb County in northern Illinois.[53] In related findings, the Onondaga, NY Health Department and the UK Department of the Environment both found that intentions to remediate were correlated generally with home radon levels.[54]

Other consistently significant correlations with intentions to mitigate were observed for:

- Beliefs about the severity of health effects;
- The perceived effect of the observed radon level on the value of one's home (i.e. intentions to mitigate increased with the belief that the effects on the value of one's home would be small if radon levels were reduced). The UK Department of the Environment found that an attitudinal variable that they called Property Pragmatism was related to intentions to mitigate in southwest England.[55]
- Self reported fear;
- The belief that one's radon level is higher than that of others in the community; and
- Knowing others who found lower levels.

Factors that appeared unrelated to mitigation plans were:

- General radon knowledge;
- Beliefs about both the difficulty and the cost of reducing radon levels;
- Presence of young children;
- Education;
- Income. In contrast, the UK Department of the Environment found that in South West England, income was related to intentions to mitigate.[56]
- Length of tenure (i.e. people who had recently moved into a home were no more likely to mitigate than people who have lived in the home for a long time).

Early Mitigation Action

There were minor differences between those who carried out home modifications one to five months after confirmatory testing, and those who said they planned to act but had not done so.

These were in:

- the degree to which people appraised their radon level as serious or dangerous;
- their beliefs about how hard it is to reduce radon to safe levels;
- whether they knew others who had found higher levels of radon; and

- the maximum level of radon in their home.

Because the magnitude of the differences between those who had acted and those who planned to act was small, the researchers suggest that, at least in the short term, the main barriers between intention and action may be something else besides the factors listed above. Weinstein and Sandman report that people who planned to act but had not done so cited:

- difficulties in choosing a mitigation method or in finding someone to carry out the procedures;
- an inability to find time to deal with the problem; and
- cost.

Eventual Mitigation Action

Follow-up surveys conducted one to two years after an initial set of surveys provided information about the factors that predicted who among the initially inactive (including the "not needed," "undecided," and "plan to act" groups) would eventually mitigate.[57] The percentage of completed home modifications was highest among those who had planned to act, lower among those who had been undecided, and lowest among those who had said that action was not needed. "Thus," said Weinstein and Sandman, "there was a clear, but far from perfect, relationship between initial intentions and eventual action." Even among those who planned to act, only 46-65% of those who had gotten follow up measurements from the NJ DEP's confirmatory monitoring program actually did mitigate. The mitigation rates among those who had been undecided and those who had said that action was not needed were substantially lower.

The factors that predicted eventual mitigation action were the same ones that lead people to decide to act:

- their perceptions of the threat posed by radon in their home (indicated by perceived danger or perceived seriousness of the threat);
- the likelihood of illness if no action is taken (the strongest predictor of an appraisal of threat); and
- the actual radon level in their home.

However, since not everyone who decides to act does so, what are the factors that explain the discrepancy? As with early mitigation action, Weinstein and Sandman suggest that the factors that determined whether or not intentions became actions were probably situational barriers (e.g. difficulty of arranging for mitigation, lack of time, cost.)

Weinstein and Sandman also stated that, "the variables we examined explained far more of the variance in mitigation intentions than in mitigation action. Action also took place over a long time span of months or even years (long term mitigation rates were about double short term rates),[1] indicating that there are significant barriers to action that must be overcome." "Taken together," the authors continued, "these findings suggest that what matters most, once people have decided to act, is a set of situational factors not examined in the studies reviewed here (except for a question asking people why they did not mitigate.) Ready access to

[1] In 1988, the University of Colorado evaluated the results of an intensive mass media campaign on radon conducted among the general public in Washington DC. Evidence from their evaluation indicated that the proportion of those mitigating did not increase over time. On average, their survey respondents had about 9 months between the time they tested and the time they were contacted to fill out the survey. However, there was substantial variability in the specific months and years in which respondents had first tested their home for radon. "If in fact the proportion of those mitigating had increased over time," the researchers wrote, "the length of time that had passed since their first test should have been a reliable predictor of whether or not they mitigated." However, the researchers found this relationship to be non-significant. Although there was no evidence that mitigation was increasing over time, it is possible that people were waiting for the results of confirmatory tests, as recommended in the EPA's Citizen's Guide, before going ahead with mitigation. However, only 19% of those in the 4-20pCi/l category (which makes up 90% of households that need to mitigate) who did not claim to have mitigated said that they had performed or were conducting a follow up test. The researchers did acknowledge the possibility that more mitigation occurred after they had conducted their survey, but they considered it unlikely. (Doyle, et. al., 1990, p35)

a radon mitigation company (whose advice is trusted), reminders to act, interaction with a helpful neighbor who has mitigated already, and even available free time may well play key roles in distinguishing homeowners who mitigate from homeowners who merely think mitigation is desirable. More research is needed to identify these factors, so that leaders who wish to motivate homeowners to mitigation action can focus on them more directly. Lowering the barriers to action – for example, by certifying mitigation companies and making their names available, may be more effective than publicizing carefully constructed informational messages or issuing emotional appeals to act."[58]

Part III. Factors Influencing Follow Up Testing

EPA recommends the Following Radon Testing Steps:[59]

Step 1. Take a short-term test. If your result is 4 pCi/L or higher take a follow-up test (Step 2) to be sure.

Step 2. Follow up with either a long-term test or a second short-term test

As with radon mitigation, follow up testing is done once a homeowner has tested his/her home for radon and received test results indicating that the radon level in their home is above the EPA's action level of 4 pCi/l. In both cases, the consumer has an indication that there is a potentially serious health risk in their home, and they are being asked to devote effort, time and money to further action. In this case, they are taking a step in this case to either rule out the threat or confirm it. As a supplement to the review of factors that influence people's mitigation decisions, the results of several studies on the factors influencing people's decision to conduct follow up testing are presented below.

Occupants of 62 rural Iowa households were interviewed three months after they received test results showing radon levels of greater than or equal to 20 pCi/l in their homes.[60]

Among those undecided about retesting, the main reasons for not performing retesting were:[61]

- They wanted more information on radon prior to proceeding with additional testing (38%);
- They were too busy, or didn't consider testing a priority (31%); and
- Their results were in the low range (13%).

The second and third reasons given by those undecided about follow-up testing echo findings regarding mitigation, namely that lack of time is a barrier to action and that the less serious a problem people perceive their home radon level to be, the less likely they are to take action.

Among those who had decided not to do follow up testing, the main reasons were:[62]

- They didn't think radon was a health risk; This group commonly stated that they had lived in their homes for many years without experiencing adverse health effects attributable to radon exposure (32%);
- Their results were in the low range (23%); and
- They planned to move soon (18%).

The first two reasons given by those who had decided not to do follow-up testing echo findings regarding mitigation, namely that the less of a serious problem people perceive their home radon level to be, the less likely they are to take action.

Fifty-five individuals who tested their residences through the Boston University Medical Center Radon Testing Services between 1988 and 1990 had levels of 4 pCi/l or above.[63] Survey responses obtained from these individuals indicated that:[64]

- Among those who did not perform follow-up testing, 42% said it was because they didn't get around to it.
- Among those with initial screening levels of 4-20 pCi/l, those who conducted fol-

low-up measurements had significantly higher initial levels than those who did not conduct follow up measurements.
- Respondents' were more likely to decide to undertake follow-up testing if the initial screening test was twice the EPA action limit.

The Boston University Medical Center survey results on follow-up testing are consistent with findings regarding mitigation, which indicate that the likelihood of action is linked to the actual radon level in a home.

Follow up Testing Intentions

As with mitigation, some researchers have examined the factors that influence intentions to act on follow-up testing.[65]

- In DeKalb County in northern Illinois, the odds of planning a follow-up test for radon were about six times higher among those who received radon test results that were above the EPA action level of 4 pCi/l, compared to the average odds across all test result categories.
- Perception of radon as a serious health hazard after receipt of radon test results was also a significant predictor of planning a follow-up test for radon.

These findings echo several of the correlations revealed by the research done by Neil Weinstein and Paul Sandman on mitigation intentions among New Jersey residents.

Part IV. Radon Testing and Mitigation During Real Estate Transactions

Radon testing and mitigation contractors state that more than 80% of the radon testing and mitigation currently being done is occurring in the context of real estate transactions.[66] Compared to the periods in which individuals are neither buying nor selling a home, it appears that real estate transactions offer stronger motives for performing radon testing and mitigation, or lower barriers, or perhaps both. What are the factors that make testing and mitigation so much more likely to occur during real estate transactions? Understanding these factors will help program planners ensure that more real estate transactions include radon testing and mitigation. This knowledge may also provide additional clues about the types of program initiatives needed to improve testing and mitigation rates outside of real estate transactions.

In the course of a thorough literature search on radon testing and mitigation behaviors, just one study was identified that examined radon testing and mitigation during real estate transactions. Its conclusions are presented below, along with important anecdotal information provided by testing and mitigation contractors on this topic.

In 1988 and 1990, University of Colorado researchers surveyed 303[2] recent home buyers in Boulder County, CO, to determine if testing at the time of home sale had become common practice, and if such testing leads to mitigation. Among other things, the researchers investigated why radon tests at time of home sale occur and how radon affects the sale negotiation process. They also investigated the differences between people whose homes were tested and people whose homes were not tested at time of sale. No extensive information or awareness campaign had been conducted in the state of Colorado as of that time, so any testing and mitigation that occurred was motivated by generally available radon information. For example, news stories indicating that Colorado had the highest percentage of homes across the country with radon levels above

[2] The researchers found that those who refused to participate in the survey were often willing to answer one question: "Was your present home tested for radon before the sale closed?" The radon testing rate for these people was much lower than for the sample who did respond to the survey. Based on this information, the researchers estimated that the testing rate for all 492 homes that were called was slightly less than the testing rate for the 303 respondents. Although they were unable to assess mitigation rates for non-respondents, they speculated that there was no reason for them to be substantially lower than the rates for respondents. (Doyle, et. al.,1990, p79)

the EPA action guideline had appeared in the news media.[67]

Survey respondents were asked if they worked for IBM, which required radon testing and mitigation to below 4 pCi/l for employees in order for them to participate in the company's housing buy back program in the event they were transferred away from Boulder. IBM employees were therefore in a very different situation than non-IBM employees with respect to radon, and were analyzed separately.[68] "In addition," said the authors, "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 in Boulder County even for non-IBM employees."[69]

Among 268 non-IBM homes, 40.7% were tested for radon before closing. Thirty-six percent of home with levels above 4 pCi/l were confirmed mitigated (i.e. a retest was done after mitigation occurred).[70]

Among a subset of 88 non-IBM homes whose buyers employed a realtor who gave them some information about radon, the testing rate (68.2%) was quite high, indicating that realtors are helping to motivate radon testing. These high testing rates are in contrast to a perspective offered by Paul Locke, Associate Professor at Johns Hopkins Bloomberg School of Public Health. He mentions that realtors are driven by commission-based selling, and therefore radon testers must work to find options that allow a valid test and do not interfere with the sale.[71]

In Boulder, among the subset of 88 non-IBM homes whose buyers employed a realtor who gave them some information about radon, the confirmed mitigation rate for those with tests above 4 pCi/l was 40%. This is good compared to rates among the general population, but there is room for improvement. The researchers speculated that "realtors may be taking responsibility for testing since it is relatively inexpensive, but do not want to take responsibility for mitigation because it is rather expensive, and they do not want to be held liable for imposing costs on a seller without legal basis for their action. Another possibility is that realtors are subject to the same lack of concern over radon levels below 20pCi/l as other people are, and see no need to ensure that mitigation occurs. Finally, realtors may not know exactly what they should be doing about radon mitigation in order to best serve their clients."[72]

Doug Wall, of Radon and Mold Professionals, described a motive for realtors that could help to overcome these potential barriers. Realtors know that home buyers often use the same real estate agent when they sell their properties. If the agent does not recommend a test when the client is buying, then the agent may be forced to recommend mitigation when their client sells the property.[73]

In Boulder County, for 180 homes for which the respondent did not receive radon information from either IBM or from a realtor, the testing rate (27.8%) was much lower, but still higher than that of the general population. The confirmed mitigation rate for these homes was 42.9%, similar to that of the homes where the realtor provided information about radon.[74]

Interestingly, the Boulder, CO survey results also indicated that people do not, or at least extremely rarely, resolve a radon problem with a seller by accepting a price reduction in place of mitigation before closing.[75] Apparently, either a high radon level is mitigated or it is not taken into account in price negotiation.

The University of Colorado researchers reported that what most of the people in the study whose homes tested above 4 pCi/l before the sale closed and were subsequently mitigated had in common was personal contact with a professional who was knowledgeable about radon, who knew what to do if the

house had a radon problem and who in many instances might have been taking some of the responsibility for making decisions about radon off the shoulders of the buyer. "This," the researchers say, "more than any other characteristic of the time-of-home sale context, is most likely responsible for the high participation rates we have described."[76]

End Notes:

[1] Morris, J. (2006)
[2] Johnson & Luken (1987) as cited in Weinstein & Sandman (1992, p65); Weinstein, Sandman and Roberts (1988) as cited in Doyle, et. al. (1990, p41); Weinstein and Sandman (1992, p79); Wang, et. al. (1999, p406); Lee & McDonald (1994), as cited in Coskeran, et. al. (2001, p7); Bradley (1996), as cited in Coskeran, et. al. (2001, p7); Denman (2005b, p7); Mazur & Hall (1990, p281); Lee & McDonald (1994, p333 & 335)
[3] Johnson & Luken (1987) as cited in Weinstein & Sandman (1992, p65)
[4] Weinstein and Sandman (1992, p68 & 79)
[5] Mazur & Hall (1990, p281)
[6] Wang, et. al. (1999, p406)
[7] Denman, et. al. (2005b, p7)
[8] Lee and McDonald (1994) as cited in Coskeran, et. al. (2001, p7)
[9] Roberts & McNees. (2005, p5)
[10] Weinstein & Sandman (1992, p65).
[11] Wang, et. al. (1999, p405 & 408)
[12] Lee and McDonald (1994, p333 & 335).
[13] Weinstein and Sandman (1992, p 76, 79 & 81)
[14] Smith & Johnson (1988) as cited in Weinstein & Sandman (1992, p65)
[15] Mazur and Hall (1990) as cited in Weinstein & Sandman (1992, p65)
[16] Sjoberg (1989) as cited in Weinstein & Sandman (1992, p65)
[17] Weinstein and Sandman (1992, p77)
[18] Weinstein & Sandman (1992, p77)
[19] Field, et. al. (1993, p443)
[20] Johnson and Luken (1987) as cited in Doyle, et. al. (1990, p2)
[21] Weinstein, Kloz & Sandman (1988, p798 & 799)
[22] In addition to the citations in this section, see also Himes, et. al. (1996).
[23] Wang, et. al. (1999, p405 & 406)
[24] Tracy, et. al. (2006, p748)
[25] Bradley, (1996) as cited in Coskeran, et. al. (2001, p7)
[26] Ryan & Kelleher (1998, p63)
[27] Lee & McDonald (1994, p333).
[28] Witte, et. al (1998, p288, 299)
[29] Roberts & McNees (2005, p5)
[30] Weinstein & Sandman (1992, p74)
[31] Himes, et. al. (1996)
[32] Weinstein, Klotz and Sandman (1989, p368)
[33] Ryan & Kelleher (1998, p63 & 64)
[34] Weinstein, Klotz & Sandman (1989, p368)
[35] Lee & McDonald (1994, p333)
[36] Weinstein, Klotz & Sandman (1989, p366)
[37] Giumond & Page (1992, p171)
[38] Witte, et. al (1998, p288, 295)
[39] Ryan & Kelleher (1998, p62 & 64)
[40] Weinstein & Sandman (1992, p79)
[41] Lee & McDonald (1994, p335)
[42] Length of Tenure in Home: Johnson & Luken (1987) as cited in Weinstein & Sandman, 1992, p65); Doyle, et. al (1990, p48 & 49)
[43] Education: (Johnson & Luken, 1987 as cited in Weinstein & Sandman, 1992, p65); Doyle, et. al. (1990, p 47 & 49); Wang, et. al. (1999, p405)
[44] Income: Johnson & Luken (1987) as cited in Weinstein & Sandman, 1992, p65); (Doyle, 1990, p 47 & 49); Wang, et. al., (1999, p405); Akerman, Johnson & Bergman (1991) as cited in Coskeran, et. al. (2001, p9); Smith, Desvousges & Payne (1995) as cited in Coskeran, et. al. (2001, p9); Lee & McDonald (1994, p335)
[45] Age: Doyle et. al. (1990, p 47 & 49); Denman, et. al (2005b, p5); Denman, et. al. (2005, p16); Lee & McDonald (1994, p335)
[46] Number of Children: Doyle, et. al., (1990, p 47 & 49); Denman, et. al (2005b, p5); Denman, et. al. (2005, p16)
[47] Weinstein and Sandman (1992, p80)
[48] Johnson & Luken (1987) as cited in Weinstein & Sandman (1992, p65); Doyle, et. al. (1990, p49); Denman, et. al (2005b, p5); Denman, et. al. (2005, p10); Lee & McDonald (1994, p335)
[49] Weinstein & Sandman (1992, p67)
[50] Weinstein & Sandman (1992, p66 & 67)
[51] Mazur & Hall (1990, p279)
[52] Lee & McDonald (1994, p334)
[53] Duckworth, et. al. (2002, p1105)
[54] Mazur & Hall (1990, p 279, 282-283); Lee & McDonald (1994, p335)
[55] Lee & McDonald (1994, p334)
[56] Lee & McDonald (1994, p335)
[57] Weinstein & Sandman (1992, p75)
[58] Weinstein & Sandman (1992, p80)
[59] http://www.epa.gov/radon/pubs/citguide.html#howtotest
[60] Field, et. al. (1993, p442)
[61] Field, et. al. (1993, p446)
[62] Field, et. al. (1993, p446)
[63] Evdokimoff & Ozonoff, (1992, p215)

[64] Evdokimoff & Ozonoff (1992, p216 & 217)
[65] Duckworth, et. al. (2002, p1105)
[66] Wall, D., & Hill, D. (Fall, 2005).
[67] Doyle, et. al. (1990, p59 & 62)
[68] Doyle, et. al. (1990, p63)
[69] Doyle, et. al. (1990, p60, 62, 63, 65)
[70] Doyle, et. al. (1990, p78)
[71] Locke, PA. (Fall, 2005)
[72] Doyle, et. al. (1990, p72 & 83)
[73] Wall, D. (Fall, 2005)
[74] Doyle, et. al. (1990, p84)
[75] Doyle, et. al. (1990. P70)
[76] Doyle, et. al. (1990, p84)

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