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WHY SCIENTISTS AND THE PUBLIC DO NOT BELIEVE IN RADON RISKS

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ABSTRACT

Risk perceptions are the basis for radon risk decisions by both scientists and the general public. Since radon cannot be detected by any of our five senses, which most people rely upon to warn them of danger, much of the general public does not perceive radon as a significant risk. Likewise, many health physicists, with many years of training and experience in dealing with significant radiation exposures, also do not perceive radon as significant. Consequently, there is considerable apathy in the United States regarding measurement and mitigation for radon. Radiation scientists also continue to raise questions about comparisons of lung cancer risks and exposure conditions between uranium mines and homes. Some scientists are questioning whether the linear model is valid for relating documented lung cancer risks in miners to the low radon doses that may occur in homes. The collective dose concept for determining population risks from radon is also drawing skepticism from scientists *and the public* who do not see evidence of risks to individuals at low radon doses.

Health physicists have traditionally been more concerned for man-made sources of radiation. Radon has always been considered a part of our natural radiation background and many feel that we should only be concerned for radiation exposures above natural background. Many radiation protection professionals also seem to find radon, at effective dose equivalents of 200 to 1000 mrem/year or more, less risky than occupational exposures to radiation at levels of 10 to 50 mrem/year. On the other hand, alpha particle emissions from radon decay products transfer more radiation energy into our body tissues than any other source of radiation, either natural or man-made. We cannot ignore this large source of radiation dose while at the same time promoting programs for radiation safety for much smaller doses from other sources.

Most people do not interpret radon risks the way they are presented by radiation scientists as statistical probabilities. People generally see an activity as risky and therefore to be avoided. Or it is not risky. Most people who were concerned for radon as a health risk decided to test and mitigate their homes in the late 1980s. Less people today are as concerned for radon risks as they are for the possibility of buying a house with a radon problem which could affect them financially. Homeowners are not inclined to spend hard-earned dollars to avert "questionable" risks from radon, even when warned by the EPA and state health agencies. However, homeowners have found a way to get radon fixed without paying for it. Namely, it is common practice to require a radon test before purchasing a home. If the radon test results are above the EPA action level of 4 pCi/L, then the homebuyer demands radon mitigation by the seller as a condition of sale. Somehow, radon seems more risky and worthy of mitigation when someone else is paying for it.

Radon apathy is also aggravated by news articles across the country in January 1995, which said "Radon Scare is a Costly Hoax." These news stories were based upon a publication of the National Cancer Institute in December 1994 (the Missouri Study), which news reporters claim, "unmasked the radon fraud with the help of some wicked facts." When homeowners read such stories, they are inclined to agree, because they see no evidence for radon risks. They are even more likely to agree when they hear that scientists are debating the risks of radon. Since the evidence for radon risks is not obvious to homeowners and since scientists are also debating the risks, it is easy for most homeowners to believe that the EPA is overstating the risks from radon.

Despite the controversy and uncertainty in radon risks, the prudent message for radon testers and mitigators

to recommend to homeowners is: "**Test and mitigate your home for radon according to EPA and state protocols.**" This message is cautious on the side of safety and in keeping with precautions that we normally take to avert other risks, such as wearing seat belts to avoid injuries in an automobile accident.

INTRODUCTION

Each of us has grown up relying on our five senses (hearing, seeing, smelling, tasting, and touching) to warn us of danger. An infant is instinctively startled by a loud sound which is interpreted instantly as a danger signal. We are taught to look where we step lest we walk into something dangerous. When we smell smoke we are alerted to the danger of fire. A bad taste may warn us of spoiled food. We also learn at an early age not to touch a hot stove because of the risk of burning our fingers. All of our senses are constantly on the alert to warn us of impending danger.

Unfortunately, today we are confronted by numerous dangers for which our senses fail to warn us. Radon is one of these sources of danger. Radon, as an inert noble gas, cannot be detected by any of our five senses. When our senses fail to give us a warning, we do not know that we may be in danger. When we have no sense of danger, it is easy to assume that no danger exists. Consequently, many homeowners do not perceive radon as a risk (Johnson 1990). Not only do homeowners not see any evidence for radon in their homes, they also do not see evidence of lung cancer due to radon. No one knows of a single person who has died of lung cancer due to radon. Most everyone knows of someone who has died of lung cancer, however, we normally assume that the lung cancer was due to cigarette smoking or some other cause.

Scientists, as normal people, also rely upon their five senses to warn them of danger. In addition, however, scientists also have insights based on measurements and risks assessments to warn them of dangers from substances that are not detectable by their five senses (Johnson 1993). For example, radiation scientists do not dispute the evidence that radon is a causal factor in lung cancer in underground uranium miners (NRC 1988). Consequently, EPA classifies radon as a Group A carcinogen in humans. This means that radon is considered a known human carcinogen based on evidence of epidemiology studies of occupational radon exposures to underground miners.

THE RADON HEALTH RISK CONTROVERSY

While scientists agree that occupational exposures to radon at high levels clearly lead to increased lung cancer risk, they do not agree on the effects of exposures to lower levels of radon typically found in homes. Attempts to relate exposure conditions and radon lung cancer risks from miners to the general population for residential exposures are fraught with uncertainties. There are many differences in exposure conditions between mines and homes. For example, miners typically work eight-hour shifts in the mine at moderate to heavy exertion. Residential exposures usually occur for 15 to 20 hours a day at mild or no exertion. Mine atmospheres often contain diesel fumes, dust, and smoke. Whereas homes usually have a smaller amount of dust in the air and these dust particles have a different size distribution than exists in mines. The miners at risk are also different than the average population. For example, most miners are adult males, whereas the average population includes women and children with different ages and medical conditions. Uranium miners are usually tobacco smokers. In the general population there are smokers, former smokers, and never smokers. Miners also have different breathing rates and air volumes related to exertion.

All of these differences between mines and homes lead to significant questions about estimating risks in residential exposures based on observed risks in mines, even at similar levels of radon or radon decay products. Many assumptions are required to extrapolate health risks from mines to homes. These assumptions, although based on the best technical data available, are open for continuous debate. One of the assumptions presently undergoing intensive scrutiny by radiation scientists is the extrapolation from actual observed radiation effects at high doses to estimated effects that may occur at low doses. The relationship between high dose effects and low dose effects is commonly represented by a straight line, called the linear non-threshold dose model, shown as Curve 1 in Fig. 1.

THE LINEAR MODEL CONTROVERSY

The linear model says that when the dose doubles the corresponding health effects should also double. This is the model most commonly used to estimate risks of lung cancer from radon exposures. The solid part of the line in Figure 1 is based on observed lung cancer incidence in uranium miners at relatively high exposures to radon decay products, typically 100s or 1000s of working level months (WLM). The solid line is then extended as a dotted line down to zero exposure. This assumes that the risk, observed at high doses, is proportional to dose all the way down to zero.

The dotted line indicates expectations or estimates of risk at dose levels for which no observations of actual risk have been confirmed. The lack of evidence for actual lung cancer incidence below about 50 WLM does not mean, however, that no lung cancers occur between 0 and 50 WLM. What it does mean is that the actual incidence of lung cancer that may be attributed to radon exposures in this dose range is a small fraction of the overall lung cancer incidence from all causes. Consequently, those lung cancers that may be due to radon cannot be distinguished from variations in the normal incidence of lung cancers. The current rate of lung cancer deaths each year in the U.S. is about 145,000 with a variation of perhaps 5,000.

Some scientists would argue that observed incidence of radiation risks would indicate no evidence of risks below a radiation dose of 10 to 20 rads or more. Such observations would support a view that no risks occur until a certain threshold level of dose is reached. The threshold model is shown as Curve 2 in Figure 1.
Some scientists would also argue that, below the threshold level for adverse effects, a region of low doses exists where radiation is actually beneficial, as shown in Curve 3 of Figure 1. This is called the radiation hormesis theory. Hormesis describes the observation that certain elements affecting our health are beneficial and even necessary in low concentrations, but in high concentrations these elements become toxic or lethal. For example, ordinary table salt is an absolute necessity for life in small amounts. However, in large amounts, such as a tablespoon quantity, salt could be very harmful. Vitamins and trace minerals behave in a similar way. The question remains open as to whether radiation may follow the hormesis principle. The possibility that a little radiation is good for you is not currently endorsed by radiation scientists.

NO SAFE LEVEL OF RADIATION

Much of the controversy about real and perceived radiation health risks today is the result of assumptions based on the linear dose-response model. The straight line extrapolation from actual observed (scientifically documented) health effects at high doses down to zero is done to provide a prudent basis for radiation protection at dose levels where effects have not yet been observed. This approach leads to the conclusion that each tiny increment of dose carries a corresponding tiny increment of risk, beginning at zero dose. Consequently, there is no "safe" level of exposure to radon, except zero. Although EPA has established an action level for radon at 4 pCi/L, even 0.4 pCi/L represents some degree of risk. This is the rationale that prompted Congress to pass the Radon Abatement Act of 1988 calling for a national goal of reducing indoor radon levels down to outdoor levels.

When the linear model was first proposed for radiation safety, it was intended to represent health effects that might occur from radiation exposures above a baseline of normal cancer incidence (some of which may be due to natural background radiation). Unfortunately, by extending the linear model down to zero dose, the model includes the low dose range of natural background radiation from cosmic, terrestrial, and internal radiation. Most people do not know that we are exposed to radiation all the time and that the amount, from cosmic and terrestrial radiation in particular, varies widely according to where we live. If we live in Florida our background radiation could be less than 50 mrem/year compared to over 150 mrem/year in Colorado (see Figure 2). Because of the linear model (no safe level theory) people are commonly demanding protection from man-made radiation sources, such as nuclear waste disposal sites, at levels of 10 mrem/year. Somehow, man-made radiation at 10 mrem/year is "unnatural" and therefore unacceptable. Whereas, radiation doses of 100s of mrem/year from background are considered natural and therefore acceptable.

In fact, radiation is radiation (alpha, beta, and gamma rays) whether the origin is natural or man-made. When this radiation strikes our bodies and deposits energy in our tissues, our bodies do not distinguish any difference between natural or man-made sources. Small variations in natural background radiation can completely overshadow exposures to man-made radiation at levels of 10 mrem/year. People also do not know that there are locations in the world with large population groups exposed to natural radiation at levels greater than 3,000 mrem/year. For example, several million people in the State of Kerala, India, are exposed to 3,000 to 3,500 mrem/year of natural radiation with no evidence of any increase in cancer or other radiation effects.

THE COLLECTIVE DOSE CONCEPT

The use of the linear non-threshold dose model for estimating health risks from radon and other sources of radiation has also led to more difficulties. The National Academy of Sciences Committee BEIR I first proposed an approach for estimating population health risks based on collective dose (NRC 1972). This is the total radiation dose received by any group of people, usually expressed in terms of person-rem, or for radon exposures, the collective dose unit is person-WLM. Collective or population dose is the sum of individual doses for the entire population or the product of the dose to an average person multiplied by the number of persons in the population. For example, the annual exposure to the average radon level in the U.S. at 1.25 pCi/L is 0.24 WLM. Collective dose for radon is then determined by multiplying 0.24 WLM times the population of the U.S. (260 million). This gives a collective dose of about 62 million person-WLM per year. From this collective dose estimate we can then determine how many people in the U.S. may get lung cancer each year from radon by applying a lifetime risk coefficient derived by EPA. Studies by EPA have shown that a collective dose from radon of a million person-WLM should result in lung cancer deaths to 224 people (after a 70 year or lifetime exposure) (EPA 1992). Therefore, the annual incidence of lung cancer can be estimated by multiplying the annual collective dose (62 million person-WLM) times the risk coefficient (224 lung cancer deaths per million person-WLM). The result is an estimated annual lung cancer incidence in the U.S. of about 14,000. Depending on a variety of assumptions used, this estimate could range from 7,000 to 35,000 lung cancer deaths a year.

The collective dose concept for estimating population radiation risk is based on the assumption (defined by the linear model) that each increment of dose will result in an increment of risk, regardless of how many people receive the dose. Thus, for radon exposures, 224 people would be expected to get lung cancer for every million person-WLM, no matter how many people are actually exposed. A million person-WLM could be the product of one million people each receiving one WLM. It could also be 10 million people each receiving 0.1 WLM or 100 million people each receiving 0.01 WLM. Since the risk is based on the total collective dose, large risks can be calculated for vanishingly small doses applied to very large populations. For example, worldwide fallout from the Chernobyl accident resulted in small radiation doses to virtually the entire population of the norther hemisphere. Thus, a very large collective dose estimate resulted in widespread news stories that tens of thousands of people would die from radiation exposures due to worldwide fallout from Chernobyl.

DIFFICULTIES WITH RADON RISK ASSESSMENTS

The first application of the collective dose concept for radon risk assessment was done by the EPA in 1973 based on the approach published by the National Academy of Sciences in 1972 (BEIR I). This was a study of the population health effects of radon in natural gas which was presented at the Noble Gases Symposium in Las Vegas, NV in September 1973 (Johnson 1973a). While the collective dose approach to radiation risk assessment has now been well established for 20 years, in 1973 it was a very new and unproven concept. In fact, after the concept was presented at this symposium of over 500 scientists from around the world, one attendee loudly proclaimed that, "This concept was the stupidest thing he ever heard of." Why was he so vehement in his criticism of the collective dose approach to risk assessment? The answer lies in the fact that the collective dose approach is based on the assumption that risks actually occur at doses far below levels with any observed evidence (the linear model). Furthermore, this approach says that we can add up very small doses to large numbers of people as a basis for estimating overall population effects.

The problem with this approach is that if effects do not actually occur to individuals at low dose levels, how can we add up the effects to estimate population risks? For example, the evidence for radon health risk at 4 pCi/L is very tenuous, at best. Breathing this level of radon for a lifetime of 70 years will result in a cumulative dose of about 54 WLM. Studies on miners have included exposures at about 50 WLM, but the evidence for health effects at this level is very uncertain. Epidemiological studies of exposures in homes at levels below 4 pCi/L have also produced conflicting results on whether any health effects can be proven. The bottom line is that at radon levels below 4 pCi/L, the actual risk of lung cancer from radon may be zero. If the health effects at this level may be zero, then clearly the effects at the national average indoor radon level of 1.25 pCi/L include zero as a possibility. And yet, EPA, the Surgeon General, and even the National Cancer Institute support the estimate that 14,000 lung cancer deaths a year may be attributed to exposures at 1.25 pCi/L. Faith in these estimates of radon lung cancer incidence is based on faith in the concepts of the linear model and the collective dose approach to risk assessments. Since neither of these concepts can be proven for low dose levels, more and more scientists are having reservations about applications of the linear and collective dose models.

RADON AS NATURAL RADIATION

Another reason that health physicists and other radiation scientists have not accepted radon as a significant source of health risk is because historically radon was considered a part of the natural environment. The primary concern for radiation safety since the discovery of x-rays and radiation in the late 1890s was protection from man-made sources of radiation. Radon, along with cosmic rays and terrestrial radiation, has been viewed as "natural" and an essentially uncontrollable source of radiation exposure. Health physicists have always been concerned for exposures from man-made radiation sources which exceed, or add to, natural radiation. Consequently, the first attempts to characterize population health risks from radon were not for natural radon in homes, but for the man-made contribution to radon in homes which use natural gas (containing radon) in unvented appliances (Johnson 1973b). Since natural gas is collected from underground sources it can contain significant amounts of radon. When the gas is burned in an unvented appliance, the radon is released into the home and becomes an additional source of exposure above natural levels due to man's activities. For many years this source of "man influenced" radiation exposure was called "technologically enhanced natural radiation" to distinguish it from "natural" radiation.

It was not until seven or eight years later that the thinking in radiation risk assessments evolved into the idea that if small amounts of man-made natural radiation could increase our health risk, then perhaps the normal levels of natural radiation could contribute to significant health effects. The first attempt to assess the population health risks of natural radiation, including radon, was met with derision by world renowned scientists at an international conference on natural radiation in Bombay, India in January 1981 (Johnson 1981). This 20-minute paper on the risks form natural radiation in the U.S. drew such critical response that the conference was totally disrupted for over an hour before the moderator could get back to the scheduled program. International attendees loudly criticized this paper as unprofessional, unethical, and scientifically unconscionable even to suggest that natural radiation could contribute to cancer deaths. The author was severely chastised for presenting risk estimates for cosmic, terrestrial, and internal radiation, and radon exposures, that would unnecessarily alarm people. These scientists were especially outraged with the estimate of risks from exposures to naturally occurring radon in homes. This paper proposed that normal radon exposures in homes could lead to 6,700 to 13,400 lung cancer deaths a year in the U.S. These scientists were upset for several reasons. Most felt that natural radiation was not a contributor to radiation health risks. Furthermore, even if the risks were real, we should not be speculating on or publicizing such information that would alarm the public, which is already overly alarmed about radiation.

RADIATION DOSE

While there may be large uncertainties in the estimates of lung cancer risks from radon exposures, one factor is especially significant. Namely, the radiation dose to tissues of the bronchial epithelium from alpha particles emitted by radon decay products is by far the largest dose from any source of radiation exposures. Alpha particles carry a large amount of radiation energy, typically 5 to 7 MeV. Since alpha particles are physically large (on an atomic scale) and positively charged, they cannot penetrate matter without quickly transferring all of their energy to the electrons of nearby atoms. The transfer of energy sufficient to knock electrons from orbit is called ionization and a typical alpha particle will produce about 150,000 ionizing events before it gives up all of its energy. All of these ionizations occur in a very short distance in solid matter (lung tissues) equivalent to the thickness of a sheet of paper. Radiation dose in units of rads is defined by the amount of radiation energy deposited per gram of material. Inhalation of radon for a year at 1 pCi/L will result in a dose of about 0.07 rads to the bronchial epithelium. A lifetime of exposure at this level would result in an alpha particle energy deposition of about 5 rads. At 4 pCi/L, this lifetime dose would be about 20 rads. BEIR IV indicates that the lifetime dose at 4 pCi/L could actually be as high as 50 to 60 rads. These doses may be compared with average lifetime doses of about 10 to 12 rads from all other radiation sources together.

To put these doses into perspective, we need to convert to units of dose equivalent in rem. This allows comparison of equivalent biological effect from alpha particle energy deposition and beta/gamma energy deposition. The conversion is: **rem = rad x Q.** Where Q is the quality factor or damage factor. Q has a value of 20 for alpha particles, which says that alpha particles cause about 20 times more damage than the equivalent energy deposition for beta or gamma radiation Therefore, 5 rads of alpha particle energy is equivalent to 100 rads of beta/gamma energy. Now to complete the comparison we have to relate energy deposition in the bronchial epithelium to an equivalent whole body dose. To determine the effect of energy deposition in the bronchial epithelium equivalent to uniform whole body irradiation, we multiply the lung dose by a weighting factor of 0.12. Thus a 70 year lifetime dose of 5 rads from 1 pCi/L of radon equals 100 rems (at 1.4 rem/year) to the lung and this equals 100 x 0.12 = 12 rem (0.17 rem/year) dose equivalent to the whole body. This dose can be directly compared to a lifetime dose of 10 to 12 rem from all other sources of radiation combined.

The significance of these dose comparisons is to emphasize that radon contributes about 50 percent of all the radiation energy deposition occurring in our bodies over a lifetime. For additional comparisons we can relate lifetime radon dose at about 12 rem to the what is legally allowed by the Nuclear Regulatory Commission for other man-made radionuclides at 0.1 rem a year or 7 rem for a lifetime. Allowable doses from the nuclear fuel cycle regulated by EPA would limit lifetime doses to about 1.8 rem (at 0.025 rem/year). EPA regulates radiation dose from drinking water to 0.28 rem for 70 years (0.004 rem/year). Furthermore, billions of dollars are proposed for cleanup of sites contaminated with radioactive materials to reduce individual lifetime exposures to about 1 rem (0.01 rem/year). These insights lead to the question, "how can radiation scientists ignore the large radiation doses from radon and continue to promote expensive programs to protect people form small amounts of radiation from other sources?"

The general public is also very concerned about disposal of radioactive wastes where doses to individuals could be from 0 to 0.01 rem/year. In fact, no one wants a radioactive waste site in their neighborhood because the fear of radiation exposures that may affect their families or future generations. For perspective, homeowners that may worry about radiation exposures from man-made sources of radiation, such as radioactive waste disposal sites, should be informed that **"their homes are presently sitting on top of a natural radioactive waste called radium."** Not only are all homes located on top of radium deposits, but the radiation dose from radon and radon decay products far exceeds any expectations of dose that may occur from radioactive waste disposal.

THE MEANING OF RISK

For most non-technical people, risk means something to be avoided, something bad or dangerous. One should not get involved with anything "risky." Many activities involving risk, however, are not viewed as risky. For example, few people think about the risk of driving an automobile as they commute to work each day. More people might think about the risk of flying, and yet those who fly do not think of flying as risky. For most people, risk is not a matter of statistical probability as scientists think about risk. For most people, events or actions are seen either as risky, and therefore should be avoided completely, or they are seen as non-risky (safe) and risk is not considered. In other words, risk is not a matter of probability, but a matter of consequences either happening or not happening. No one driving a car expects to have an accident. Everyone playing the lottery expects to win.

Radiation scientists, skilled in the art of risk assessment, try to explain the significance of radon exposures to people by expressing the risks in terms of how many people may get lung cancer out of a thousand people exposed to a given amount of radon. For example, the EPA *Citizens Guide* says that out of 1,000 people exposed to 4 pCi/L of radon for 70 years, 2 could get lung cancer if they have never smoked, or 29 if they are smokers. This guide does not point out the flip side of the coin. That is to say, out of 1,000 people exposed to 4 pCi/L, 998 never smokers would not be expected to get lung cancer. Likewise, 971 smokers would not get lung cancer from radon exposures. Therefore, homeowners have to decide whether they believe they will be one of the 2 never smokers who may get cancer, or one of the 998 who will not.

Since most people decide on risks on the basis of an event either happening or not happening, then the statistics of risk probabilities have no meaning. Therefore, 2 out of 1,000 or 29 out of a thousand are not seen as different. In fact, risk probabilities of 1 in 1,000, 1 in 10,000, 1 in 100,000, or 1 in 1,000,000 are all seen as the same level of risk. For the person making the risk decision, the conclusion is still the same. Either the consequences will happen or they will not. Therefore, from a "risk" versus "no risk" perspective, we should not be surprised that the public is largely viewing radon as "non-risky."

When the public first heard about the risk of radon as a significant cause of lung cancer in the press releases of EPA and the Surgeon General in October of 1988, great alarm spread across the nation. Much of the alarm was probably due to the new idea that significant radiation existed in homes from a previously unknown source. The reaction was probably related to common fears about radiation. Images of mushroom clouds still link the word "radiation" to death and destruction. For many people radiation means cancer. For these people, risk decisions are based on the belief that the most terrible consequences of exposure to radiation will happen to them. They believe that if radiation is present, it is bad for you and should be avoided completely. These people were frightened about radon as a radioactive gas and quickly tested their homes to determine if this terrible radioactive material was present. If the amount was above 4 pCi/L, it was determined to be present and unsafe or dangerous. If below 4 pCi/L, the home was safe.

Most of the people reacting to EPA's radon risk statements in 1988 believed that if radon was present then they would suffer the consequences, i.e. they would get lung cancer. These people believed that they would be one of the 2 in 1,000 that would get lung cancer. These people made the normal "all-or-nothing" risk decision and decided to test and mitigate to assure that radon risk was completely removed. The panic response to radiation in the sanctity of people's homes led to massive buying of radon test kits. This demand for radon tests fueled the birth of the radon measurement industry. Unfortunately for the new radon industry, the numbers of people reacting to the radon scare, based on the all-or-nothing approach to risk decisions, reached a peak within 2 to 3 months and just as quickly dropped off in early 1989.

LACK OF MOTIVATION TO TEST FOR RADON

Since 1989, more homeowners are deciding that even if radon is present, they will be one of the 998 out of a 1,000 that will not get lung cancer. Consequently, they are not even motivated to test their homes to find out if radon is present or above the EPA guidelines. Those who smoke, understand that their risk from radon exposures is greater than for never smokers, but also the greater risk is still from smoking alone. Since smoking is an addictive habit, these people are not willing to stop smoking. They rationalize either that they will not be a victim of lung cancer from smoking and, therefore, why should they believe that they will get lung cancer from radon instead. Or, they believe that they may get lung cancer and are resigned to their fate. Everyone has to die of something. For them, lung cancer is already a perceived reality and so why should they worry about radon causing lung cancer when cancer is the likely outcome of smoking.

The result of the all-or-nothing approach to radon risk decisions has been fewer and fewer homeowners testing for radon because of concerns for health risk. Besides, it is easy to decide that radon in not really risky when you look at the evidence. When homeowners look around for evidence of the 15,000 or 20,000 people that are supposed to be dying each year from lung cancer caused by radon, they do not find even a single body. No one knows of a single person who has died of lung cancer from radon exposures. Therefore, the consequences of exposure to radon gas do not seem real. When a homeowner looks at EPA's risk estimates that state 2 people out of 1,000 may get lung cancer at 4 pCi/L, the homeowner concludes that EPA must be talking about some other part of the country, because there is no such evidence in their neighborhood. In other words, the radon risk is someone else's and does not apply to them individually.

On the other hand, a new trend is developing in this country. While people are not as concerned with the health risk of radon, they are greatly concerned about buying a house that may have a radon problem. Therefore, more and more homebuyers are requesting radon testing before they complete a contract to buy a home. If the radon test (by EPA real estate protocols) shows results above 4 pCi/l then the homeowner is being required to mitigate the home as a condition of sale. It is interesting that a homeowner may not consider testing or mitigating his own home, but will not buy a house unless someone guarantees that it is safe from radon. Apparently, radon is more risky and therefore worthy of mitigation when someone else will pay for it. The motivation in such cases would appear to be more financial rather than concern for health.

NEWS MEDIA INFLUENCE

Radon apathy was also aggravated by news articles across the country in January 1995, which said "Radon Scare is a Costly Hoax." These news stories were based upon a publication by the National Cancer Institute in December 1994 (the Missouri Study, NCI 1994). This study concluded that, "an association between lung cancer and the exposure to domestic levels of radon was not convincingly demonstrated. The magnitude of the lung cancer risk from radon levels commonly found in U.S. dwellings appears low." News reporters picked up on this conclusion and claimed that this study, "Unmasked the radon fraud with the help of some wicked facts." When homeowners read such stories, they are inclined to agree, because they see no evidence for radon risks. They are even more likely to agree when they hear that scientists are debating the risks of radon. Since the evidence for radon risks is not obvious to homeowners and since scientists are also debating the risks, it is easy for most homeowners to believe that the EPA is overstating the risks of radon.

The news media did not react to the Editorial by Jonathan Samet in the same publication of the Journal of the National Cancer Institute (NCI 1994). Samet noted that many case-control studies have been conducted since the 1980s to directly measure the risk of indoor radon. All of these studies, however, lack sufficient sample size (participants) to draw statistically defensible conclusions either for or against the relationship of radon and lung cancer at levels normally found in homes.

News media have also not picked up on the July 1995 report by Jay Lubin (NCI 1995) which concluded that radon may account for 14,400 lung cancer deaths a year in the United States, and may be responsible for up to 30 percent of lung cancers among nonsmokers. These conclusions were derived from a review of 11 studies of lung cancer in hard-rock miners. This review analyzed 2,700 cases of lung cancer among 65,000 underground miners.

WHAT DO WE TELL THE PUBLIC?

After consideration of some of the uncertainties on radon risk estimates outlined above, what is the bottom line that we can present to the American public? The basic principle for public health and safety is always to err on the side of over protection. Consequently, even with the ongoing debate about the real risks from radon the prudent public health message should still be,

> *"Test your home for radon and mitigate if the levels are above 4 pCi/L, according to EPA and State protocols."*

The linear model says that lowering radon levels will lower your risk, no matter what level the risk may be. In addition, many homeowners are now finding that sub-slab suction systems also produce other benefits. These include drier basements and lower levels of airborne molds and fungi, as well as reductions in other soil gases that may enter homes with radon. Furthermore, a cautious approach to radon is in keeping with similar precautions that we take for other risks, such as wearing seatbelts and driving at the speed limit.

CONCLUSIONS

Most people, including scientists, rely on their five senses to warn them of danger. Radon as an invisible, inert, and odorless gas does not trigger any of our senses to alert us to danger. Also, no one knows of a single person who has died from lung cancer due to radon exposures in homes. The evidence for lung cancer risks is based on observations of excess lung cancers in underground uranium miners. The exposure conditions for miners, however, require numerous adjustments for estimating comparable risks in homes. The procedure for estimating risks in homes assumes that cancer incidence observed in miners at high radon levels will yield a proportionate incidence of lung cancers in homes by a straight line relationship down to zero radon levels. Thus, risks are estimated by a linear model down to low radon levels where no actual lung cancers have been observed. Not all scientists believe that the linear model applies to radon. Some would even suggest that low levels of radon are beneficial.

The linear model says that all levels of radon carry some risk all the way down to zero. Consequently, by this model there is no "safe" level of radon. Studies to confirm health risks at low levels of radiation, however, are complicated by normal variations in natural background radiation and the normal incidence of cancer. The use of the linear model has been extended as a way of estimating population risks by the concept of collective dose. The approach for estimating risks in large groups is to determine what is the total radiation dose received by the group (collective dose) and then apply risk coefficients provided by the National Academy of Sciences to determine how many cancers may occur in that group. For radon, this approach is based on the number of lung cancer deaths expected for each million person-WLM. The conceptual difficulty with the collective dose approach is that it takes small doses (for which no effects are observed) and adds up those doses for all the people in the exposed population as a basis for estimating the effects in that population. This is the approach used by EPA for estimating 14,000 lung cancer deaths a year in the U.S. attributed to lifetime exposure to 1.25 pCi/L of radon.

Health physicists have historically been concerned mainly with protection from man-made radiation. Consequently, radon has been considered as part of natural background radiation which is not controllable and should be accepted because it is natural. The first attempts to estimate risks from radon were met with loud criticism in 1981.

Radon is by far the largest source of radiation energy deposited in our bodies from all radiation sources. At 1 pCi/L, a lifetime of exposure (70 year) would result in a whole body dose equivalent of about 12 rem. This may be compared with a 70 year limit, regulated for man-made radionuclides by the Nuclear Regulatory Commission, of 7 rem for the general public.

Most people do not interpret risks in the way intended by scientists who present risks as statistical probabilities. For most people, an event either will happen or it will not. Many people upon first hearing about radon in the late 1980s decided the risk was not acceptable and decided to test and mitigate. Today, fewer people are testing because of concern for radon health risks. However, more are testing because they do not want to buy a house with a radon problem and they have found a way to get someone else to pay for testing and mitigation as a condition of sale.

The news media is reflecting the public's perception of radon risks and criticizing government programs that seem to be based on no real evidence for radon risk in homes. Most reporters seem more inclined to report studies or statements from scientists that minimize the radon problem, because these fit the popular perception that radon is not an obvious problem.

Despite the controversies on radon risks, the most prudent message for us to present to the public is to test and mitigate for radon. The cost is low and in keeping with cautions we would normally take to minimize other sources of risk.

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Figure 1. Radon - Lung Cancer Risk Models

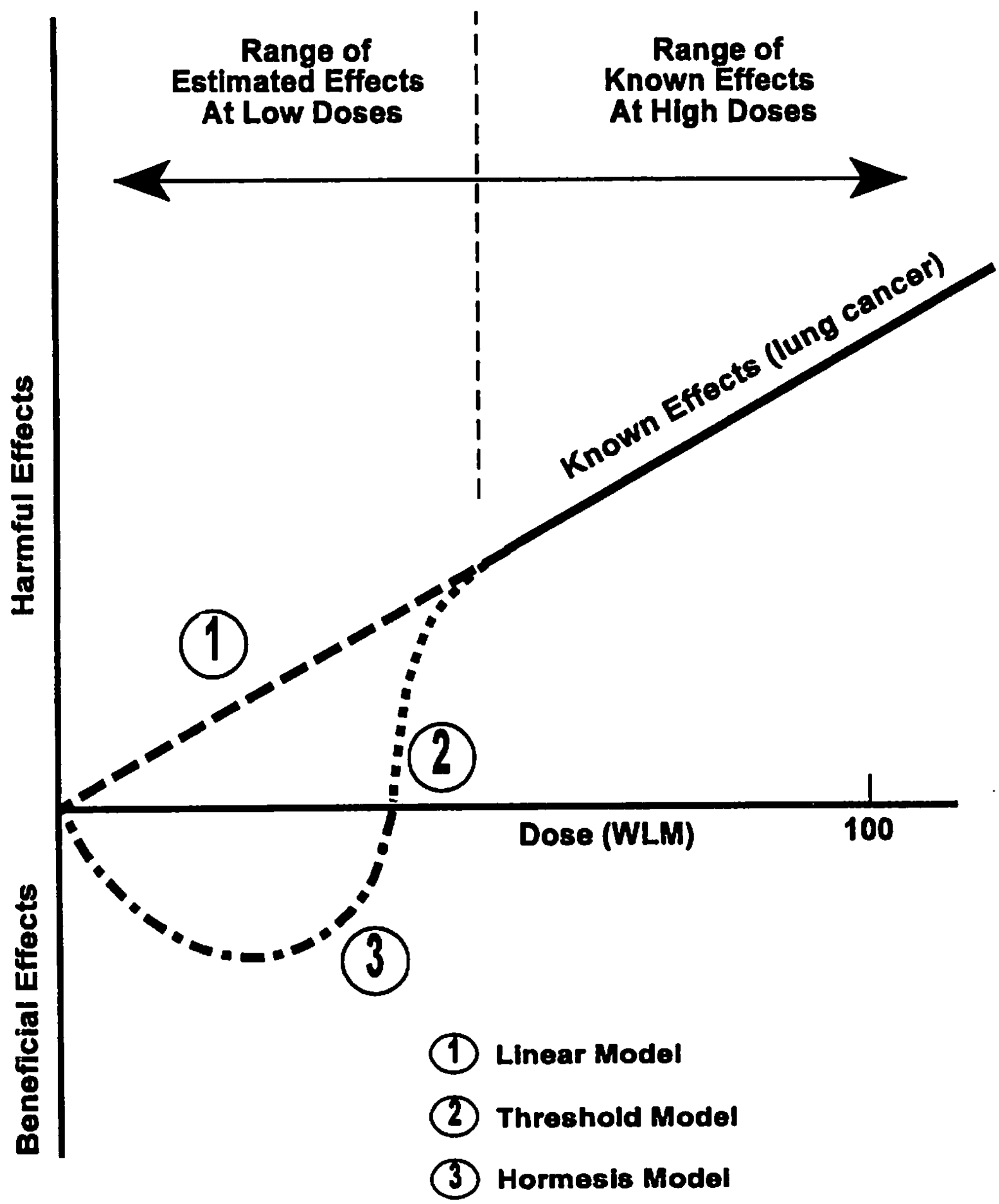
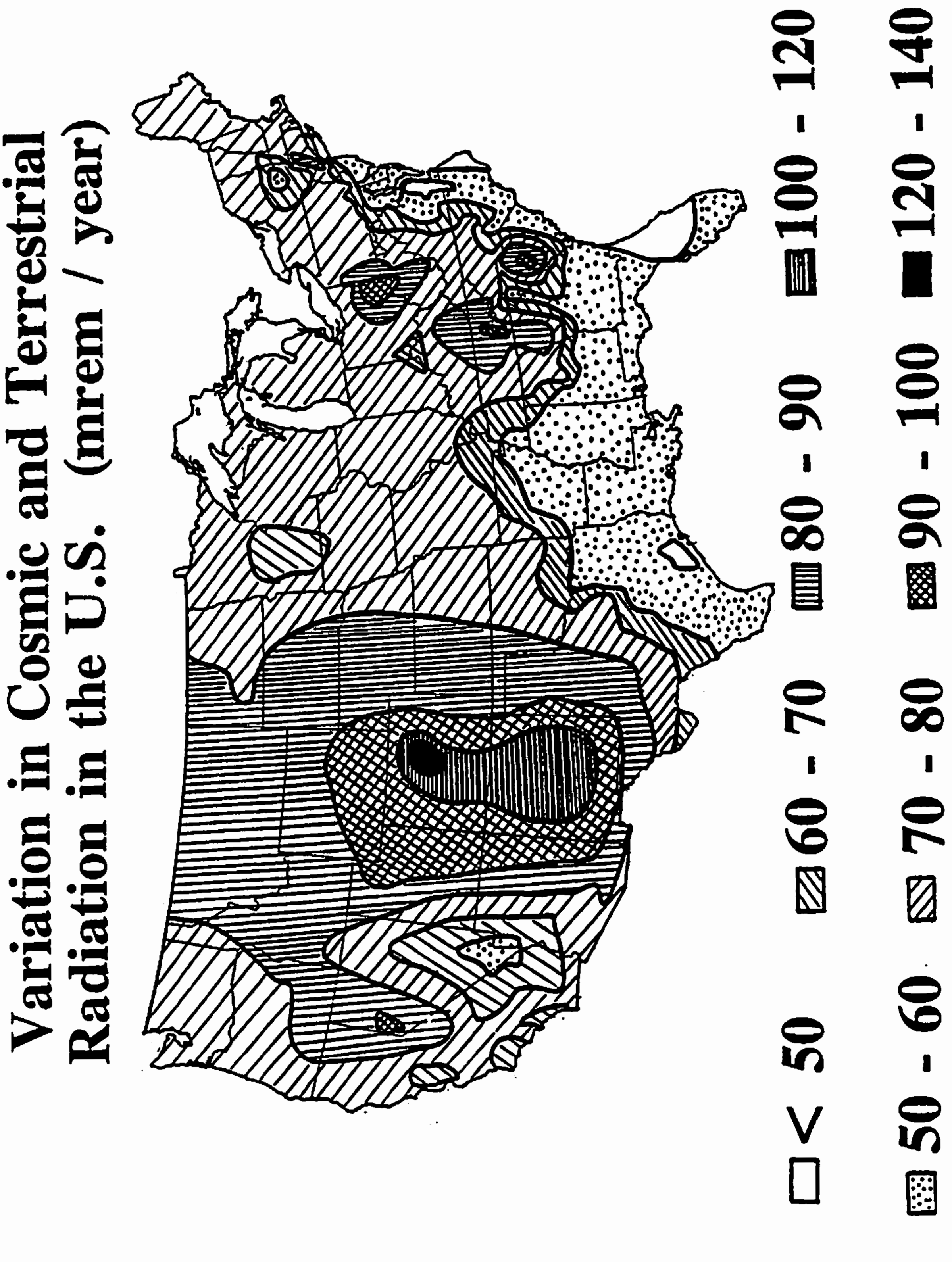


Figure 2.


Variation in Cosmic and Terrestrial
Radiation in the U.S. (mrem / year)
< 50
60 - 70
80 - 90
100 - 120
50 - 60
70 - 80
90 - 100
120 - 140