#5462

I-4

THE US DOE RADON RESEARCH PROGRAM:

A DIFFERENT VIEWPOINT

Dr. Susan L. Rose
Office of Energy Research
US DOE
Washington, D.C. 20585

ABSTRACT

The United States Department of Energy, Office of Health and Environmental Research (DOE/OHER) is the principal federal agency conducting basic research related to indoor radon. The OHER has supported research on the biological effects of ionizing radiation for many decades and is responsible for the scientific knowledge upon which occupational exposure standards are based. Legislative mandates, including the Atomic Energy Acts of 1946 and 1954, The Energy Reorganization Act of 1974, and The Federal Nonnuclear Energy Research and Development Act of 1974, provide the broad authority under which the radon research program is funded.

In 1987, the OHER targeted several million dollars of support for basic research targeted toward evaluating the health risk of environmental levels of radon. In 1989, this program expanded again to an annual level of approximately $11-13 million. The scientific information being sought in this program encompasses research designed to determine radon availability and transport outdoors, modeling transport into and within building, physics and chemistry of radon and radon progeny, dose response relationships, lung cancer risk, and mechanisms of radon carcinogenesis. The main goal of the DOE/OHER Radon Research Program is to develop information to enable an improved health risk estimate for radon exposure and thereby facilitate sound public policy decisions.

Introduction

The Department of Energy (and its predecessor agencies) is an historic participant in radiation issues currently facing the U.S. government and U.S. population, as both a generator of radioactive materials and as the leading radiation research organization. Indeed much of the basic knowledge of radiation effects which underlie occupational radiation standards comes from DOE research efforts. This paper is directed toward a discussion of the radon research program, the major radiation research program currently supported by the Office of Health and Environmental Research.

This program, basic in nature and mandate, has not been able to keep abreast of the radon policies rapidly being developed by the US EPA, nor adequately provide for the immediate scientific needs of a burgeoning radon industry that is often driven by economic factors. Scientific uncertainty on radon risk, the key factor driving the DOE radon research program, often differs in perspective from radon action and risk communication interests. The inherent "give and take" between science and action contribute to more balanced and reasonable policy choices.

THE DOE RADON PROGRAM: UNCERTAINTY REDUCTION (Figure 1)

Addressing areas of uncertainty is the focus of the DOE Radon Research Program. Six specific areas of research have been developed to describe the areas in which information is needed. These six areas are discussed below.

In most cases, radon found in homes originates from the soil around and beneath the house. However, the exact relationship between the occurrence of radon in the soil and the amount of radon available for transport into the home remains unknown. To address questions regarding the levels of radon progeny likely to be found in homes and other buildings, OHER has established the following two program areas: Availability and Transport of Radon in Soil and Transport of Radon into and within Buildings.

The dose of radon progeny and thus radiation received is dependent on a number of variables in addition to the overall level of radon in the building. These variables include the fraction of the radon progeny attached to particles and the size distribution of the particles, among others. To investigate how these parameters affect the dose of radiation received by an individual, OHER has established the following program areas: Physical/Chemical Interactions of Radon Progeny in Air and Relationship Between Exposure and Dose.

Although underground miners exposed to elevated concentrations of radon have been shown to contract lung cancer, the exact biological effect of radon on the lungs and the reason this effect causes lung cancer remain unknown. Two areas of the research program are directed at examining the types of damage caused to cells by radiation from alpha progeny and how this damage ultimately results in lung cancer. These two program areas are the following: Mechanisms of Lung Cancer Induction and Quantification of Cancer Risk from Radon Exposure.

MANAGEMENT OF THE RADON RESEARCH PROGRAM (Figure 2)

The DOE technical staff developed the original research program goals and continue to guide the program tasks in support of the attainment of these goals and the reduction of critical uncertainties. These tasks include the evaluation and selection of research projects relevant to the reduction of uncertainties; the continual coordination, maintenance, and review of the projects; and the promotion of exchange of research findings among members within the national and international radon research communities. In these tasks, management is assisted by a panel of principal scientists selected from among the researchers participating in the program. These scientists, chosen to represent different disciplines, work together to ensure that levels of technical quality and relevance of program activities meet high standards.

Development of Relevant and Coordinated Program Goals

The Radon Research Program coordinates research goals and share information with other national and international programs. While OHER has for some time coordinated its efforts with other DOE offices, such as the Office of Conservation and Renewable Energy, the Office of Nuclear Energy, the Office of Environment, Safety and Health, and the Bonneville Power Administration, recent efforts have broadened the scope of the coordination to include other agencies, both Federal and International.

DOE signed a Memorandum of Understanding to coordinate its research efforts with those of the Environmental Protection Agency (EPA). As a result, DOE has taken responsibility for conducting basic research related to radon, particularly as it relates to public health. EPA has taken responsibility for conducting applied research, public outreach, and operational programs involving the states and the private sector.

The DOE Radon Research Program, now over four years old, is mature enough for a reevaluation of the research vs. uncertainties and risk. An effort to identify contributions to risk assessment approaches with this newly available data will commence in 1991 with an initial planning meeting of key scientists.

DOE also signed a Memorandum of Understanding with the Commission of European Communities (CEC) and meets annually with the managers of the CEC Radon Program to coordinate activities. The program managers have agreed to hold annual meetings, review each other's programs, and cooperate in the funding of international workshops on radon research findings. Emphasis is being placed on conducting complementary research programs across national boundaries.

A major scientific accomplishment occurred in July 1989, when over 50 participants representing many different countries attended an International Workshop on Residential Radon Epidemiology sponsored by DOE and CEC. Discussions focused on assessment of lifetime radon exposure, design considerations for residential radon epidemiological studies, and statistical power and data analysis. Participants concluded that pooling data from different studies was essential to obtain quantitatively useful information. Participants also emphasized the relationship (or lack of) between the needs of policy makers and the capacity of epidemiological investigations to satisfy these needs. Plans now call for a repeat workshop of the epidemiology investigators in the summer of 1991 to plan a meta-analysis of their combined data when it is available.

The DOE Radon Research Program manager co-chairs with EPA, the Federal Interagency Committee on Indoor Air Quality (CIAQ) Radon Work Group. This work group coordinates activities among all Federal agencies involved in radon research. Members meet regularly to exchange information and review and comment on technical documents. In addition, special activities, such as the development of a Federal Radon Activities Inventory, have been undertaken.

DOE is also a participant of the Committee on Interagency Radiation Research and Policy Coordination (CIRPPC). This committee is comprised of members of all the Federal agencies conducting radiation research.

Funding of Selected Projects

Radon Research Program management supports the attainment of the research goals by selecting and funding projects likely to produce information needed for reducing uncertainties. The Radon Research Program management sets priorities for research activities through an evaluation and ranking of proposals. In FY 1987, OHER solicited applications for funding and received 128 research proposals. The proposals were reviewed and projects were selected to receive funding based on scientific merit and relevance to program initiatives.

Funded projects are reviewed continually on an informal basis. A formal scientific peer review process was undertaken in FY 1990 and evaluated the entire radon program. A significant number of projects were terminated and recommendations were made for program redirection, adding risk assessment and modelling components. Management staff will use significant research developments revealed in the formal review process to target the next three-year phase of the program, incorporating the change in emphasis in their selection of the next round of projects for funding.

Information Flow

DOE hastens the progress toward program goals by facilitating the flow of information among research laboratories, other agencies, national and international committees. The ready exchange of information serves to maximize technical input on research projects and helps to prevent duplication of activities.

The panel of seven principal scientists from various research disciplines serves to facilitate communications between the managers and radon scientists. The group meets to evaluate the status of the program with regard to the quality, relevance, and cohesiveness of the research being conducted and to exchange information.

Meetings

The Radon Research Program conducts an annual contractor meeting of all OHER radon researchers, radon technical staff, and guests from other Federal programs. The scientists highlight accomplishments, resolve problems, share collaborative results, and address changes in program emphasis.

OHER also plans small workshops for the various research areas. Specific goals for each meeting are identified, and other scientists are invited as the needs for specific expertise are identified.

Publications

Each year, the Radon Research Program publishes a research program update with project summaries and accomplishments. In 1990 it began the publication of a newsletter which highlights radon research activities in DOE and elsewhere. This can be obtained at no cost by writing Gloria Caton, Oak Ridge National

Laboratory, Oak Ridge, Tennessee 37831.

A series of technical radon documents continues each year as topics are identified and manuscripts are completed. Several documents on epidemiology and animal studies have been completed in the last several years.

The Radon Research Program oversees and funds the research activities of a national network of over 60 projects in university, private, national, and contractor-operated laboratories. In addition, the program manages various activities which promote the exchanges of information among all radon research programs, both nationally and internationally, in order to promote the reduction of uncertainties surrounding human exposure to radon.

UNCERTAINTIES: AN OVERVIEW [FIGURE 3]

Reducing radon uncertainties is the goal of the DOE Scientific Research Program. This program has evaluated these uncertainties, determined those which are amenable to scientific methods, and is attempting to address many of the most outstanding questions. The major uncertainties in Radon Risk are listed here as a broad overview of the research issues.

Miners vs. Public

Using observations in underground miners as a basis for estimating the risks of radon to public health yields a risk estimate containing major uncertainties. Some of the uncertainties exist within the *miner* data and make the *risk* estimate calculated for miners uncertain. Other uncertainties are added when the miner estimate is used as a basis for predicting health risks to the public because of differences that exist between mining and residential exposures and between miners and other members of the population. An EPA sponsored National Academy of Science Panel on dosimetry has explored this issue and will be publishing its findings this year. Although there is general scientific agreement that exposure to radon progeny is associated with an increased occurrence of lung cancer in miners, there remains some uncertainty as to the relationship between the extent of exposure and risk, even in miners.

Potential Errors in Measurement

A major source of uncertainty in most scientific radon studies is the validity and accuracy of the radon measurements used to determine exposure. Using currently available techniques, radon measurements may vary from some "actual" or calibrated level by more than twenty-five percent. Also, differences in readings may arise as a result of variations in monitoring, calibration, and quality control procedures. This issue is further complicated in radon studies because technical limitations discourage the direct measurement of radon progeny, the factor causing the lung cancer.

37

Potential Errors in Exposure

Radon levels fluctuate throughout the work day and from place to place within a mine. Consequently, the exposure level for a given individual may differ from the level at the time and place the measurement was taken. In fact, in many miner studies, the levels were not measured during the period of exposure but were estimated based on measurements acquired more recently or "guestimated" from other sources.

Potential Errors in Diagnosis

In addition to errors in the exposure estimates, there may be errors in the number and kind of lung cancer cases diagnosed for the members of the studies.

Potential Errors in Model Selection

Selecting an appropriate model for relating the history of exposure for the study subjects to the observed lung cancer rate is a complicated task. For example, how do you quantitate the exposure of an individual who spent five years in a mine over twenty years ago? How does this compare with a person exposed for five years just five years ago? In the case of radon, model selection is particularly difficult because two of the variables, radon and cigarette smoke, are believed to interact.

ENVIRONMENTAL CONDITIONS

Another category of uncertainty is a result of the inadequate understanding of how the environmental conditions that predominate in a mine contribute to the health effects seen in miners, and how these environmental conditions compare to those found in a home.

Factors, such as the distance to the source of the radon and the amount of ventilation, influence the concentration of radon progeny present in the air. If everything else is equal, the higher the concentration, the more radiation that may be available to be inhaled. But generally everything else is not equal, and the relationship between exposure level and dose is not straightforward. At least two other environmental parameters affect the dose-the number and size of particles in the air.

Differences in Environmental Sources

Environmental conditions and radon sources within mines are relatively constant compared to conditions and inputs to homes. Radon levels within homes can vary more than an order of magnitude, depending on environmental factors such as climate, season, wind speeds, pressure differences, humidity, and radon emanation potentials from heterogeneous soils and rocks.

Differences in Levels of Radon Progeny in Mines and in Homes

Although some homes have been found with extremely high levels of radon, the majority of homes have levels much lower than those generally found in underground mines. Currently there is very limited information about the health effects associated with radon at the levels commonly encountered by the public. As a result, some of the uncertainty in the risk estimates stems from having to extrapolate risks that are likely to occur at the low concentrations of radon commonly found in homes from data about the higher concentrations found in mines.

Differences in Particle Sizes and the Unattached Fraction

Investigators of homes in New York and New Jersey and mines in Colorado and Canada have shown the sizes of particles differ in the two environments. Poor ventilation in mines and the preponderance of dust-generating activities keeps the concentration of airborne dust high and perhaps the fraction of unattached particles low. Although recent improvements in ventilation in mines have reduced the concentrations of dust, this has been counteracted by an increased use of diesel driven equipment. Unattached fractions in mines have been found to range from less than 1% to as high as 16%.

Various activities within the home such as cooking and smoking contribute to the prevalence of particulate matter in indoor air and affect the fraction of attached progeny found in homes. However, many of the aerosol creating activities are reduced at night when residential exposures predominate and consequently the particulate concentration is also reduced. Unattached fractions in homes have been measured to range from below 5% in the presence of specific aerosol sources to between 6% and 15% in the absence of the sources. This value indicates that the unattached fraction in homes may be twice as high as that found in mines although more adequate information is needed for mines.

Other Toxicants

Toxic air pollutants, such as those found in diesel exhaust, can accumulate in the air of mines due to confined conditions and inadequate ventilation. The contributions of these pollutants to the effects observed in miners is unknown.

Additionally, most of the miners that have been studied were cigarette-smokers. Not only does cigarette smoking itself lead to lung cancer, the presence of naturally occurring radionuclides in tobacco contributes to the overall radiation exposure. It is believed that the combined effect of radon progeny exposure and cigarette smoking is multiplicative. As a substantial portion of the general population is nonsmoking, the extrapolation of effects from a predominantly smoking miner population to other members of the public may result in an overestimated risk.

39

UNCERTAINTIES IN CHARACTERISTICS OF THE EXPOSED POPULATION

A final category of uncertainty results from a poor understanding of the actual differences in the physical characteristics of miners and members of the general public and how these factors affect risk. Even if the same environmental conditions prevailed in mines and in homes, uncertainties would remain because differences in sex, age, smoking status, and activity level affect an individual's response to radon exposure.

Amount of Air Inhaled per Unit Time

During the period of exposure, miners are expected to be participating in relatively strenuous activities. As a result they are likely to be breathing deeply and frequently. In contrast, residential exposures generally take place when individuals are involved in light activity or are sleeping. Under these conditions, breathing is likely to be shallow and slow.

The increased volume of air brought into the lungs brings in a greater amount of radon progeny; however, the increased frequency of breathing decreases the mean residence time of aerosols in the lung and consequently, reduces the time available for diffusion to deposit particles on the bronchial airways.

Oral vs. Nasal Breathing

The dose of radon progeny delivered to the lungs can be influenced by the proportion of oral and nasal breathing because larger portions of some sizes of particles are deposited in the nose during nasal breathing than in the mouth during oral breathing, though the significance of this difference is not known.

Differences in the Lung Characteristics

The dose of radon progeny is dependent on the amount of material deposited in the lungs which in turn is dependent not only on the factors mentioned above, but also on the sizes and branching patterns of the airways. Size and branching factors can vary with the sex and age of the exposed individual. The geometry of the female airway is similar enough to that of the male that the use of scaling factors can probably account for differences. The same is not true for children, however. The extent to which the adult miner data need to be adjusted to account for different lung characteristics is uncertain, particularly for children. This is further complicated by reports of a National Cancer Institute epidemiological study of miners exposed as children to radon while working in tin mines in China in which it was reported that there was no evidence of an increased incidence of lung cancer from these early exposures.

The dose is also dependent on the rate at which deposited materials are cleared from the lungs. Clearance rates are affected by smoking status and age, and it is important to consider differences in these parameters when comparing miners and the general public. There are no data on clearance rates for children.

UNCERTAINTIES IN EXTENT AND DURATION OF EXPOSURE

In addition to differences in environmental and physical factors, significant differences in the timing of exposure exist between miners and the general population. For the general population, exposure may begin at birth and continue throughout the lifetime or until the radon is detected and remedial action is taken. The effects of the differences in the timing of exposure between miners and the general population are difficult to judge and add uncertainty when miner risk estimates are used to predict risks to the public.

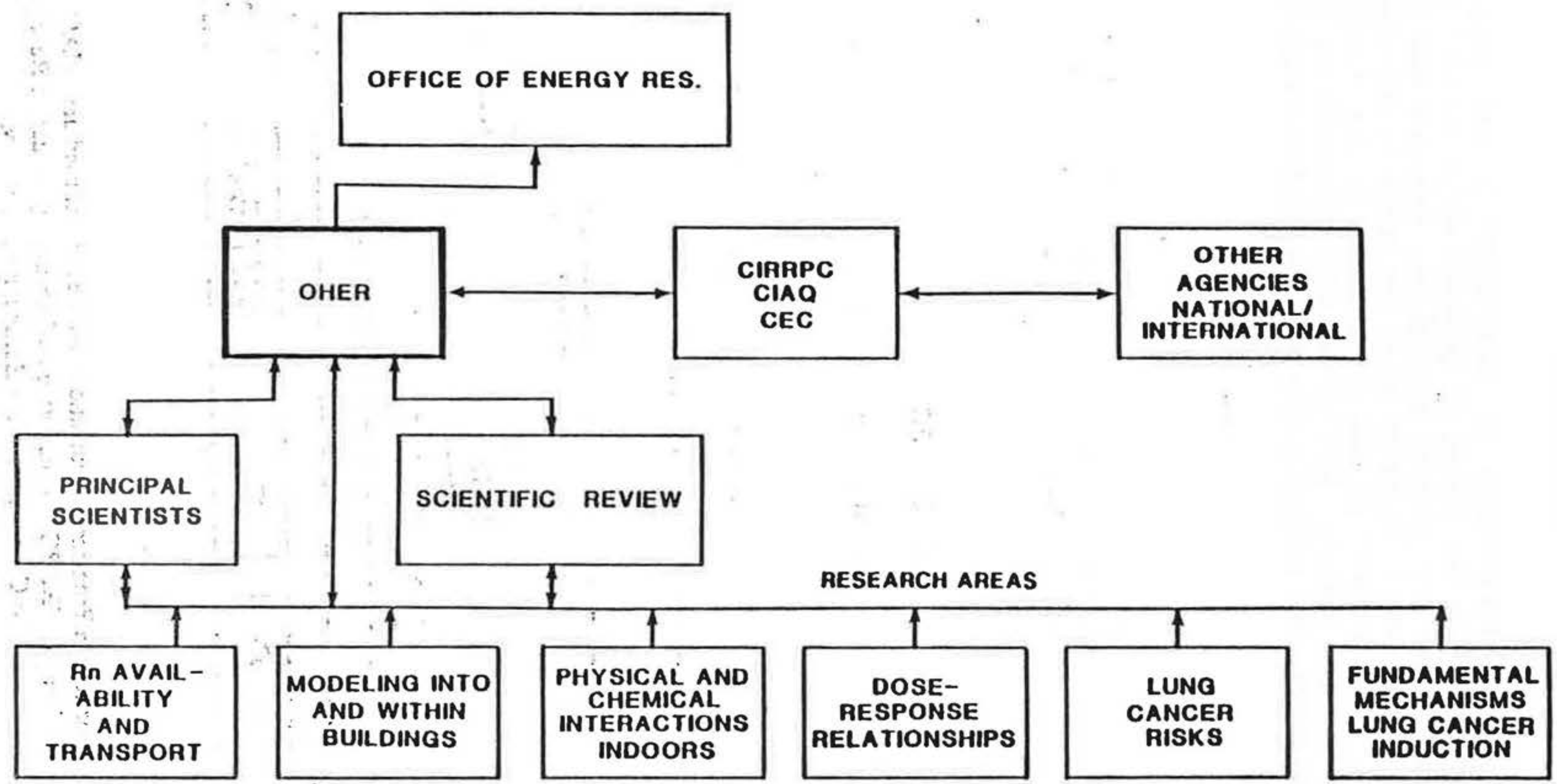

Figure 1. Principal Elements of the DOE/OHER Radon Research Program.

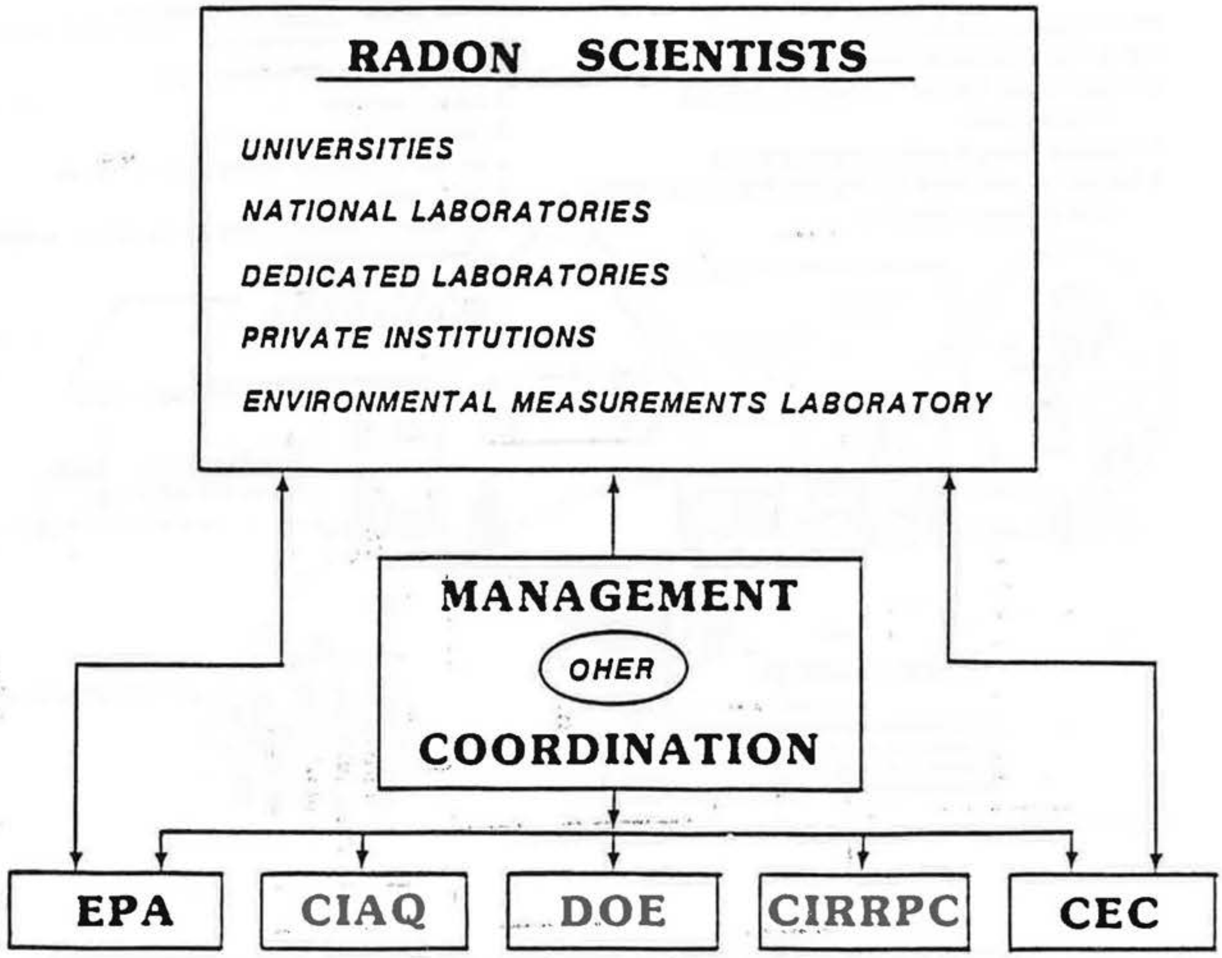

Figure 2. Mechanisms for Radon Program Coordination. Abbreviations used are: CIAQ = Committee on Indoor Air Quality, CIRRPC = Committee on Interagency Radiation Research and Policy Coordination, and CEC = Commission of the European Community.

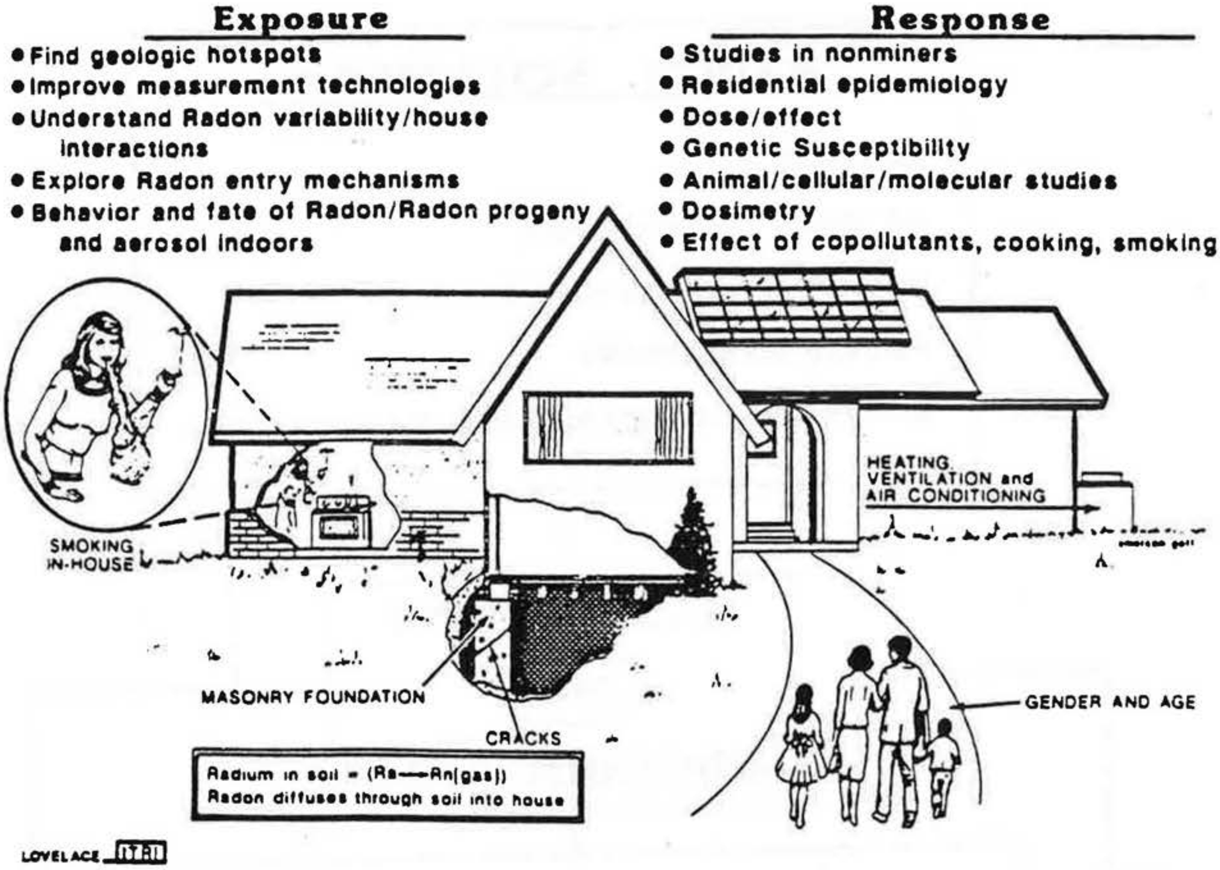

Figure 3. Sketch Illustrating Some of the Uncertainties in Estimating Lung Cancer Risk from Indoor Radon Progeny.