# U.S. ENVIRONMENTAL PROTECTION AGENCY
# REPORT TO CONGRESS ON INDOOR AIR POLLUTION AND RADON
# UNDER
# TITLE IV
# SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT OF 1986

April 1987

# INTRODUCTION

The purpose of this document is to fulfill the requirement set forth in Title IV, Section 403(d) of the Superfund Amendments and Reauthorization Act of 1986 (SARA), that the Administrator of the United States Environmental Protection Agency (EPA) submit to Congress a plan for implementing indoor air and radon research programs within the Agency. In light of the Agency's current schedule for reviewing research needs and developing a long-term research program in indoor air, this document does not present a final implementation plan for indoor air. Rather, EPA is responding to the 90-day statutory deadline by providing Congress with the following information:

- Background information on the Agency's involvement in indoor air quality problems and EPA's current policy for addressing the overall problem of indoor air pollution (Chapter 1);

- The activities, both programmatic and research, underway to formulate a long-range indoor air program (Chapter 2); and

- The Agency's indoor radon program, which includes a detailed description of EPA's research and programmatic activities (Chapter 3).

A detailed plan for implementing an Agency-wide program on indoor air, including a description of the multi-year research program which will support the Agency's indoor air efforts, will be forthcoming in the near future.

Regarding the Title IV requirement that the research programs in indoor air and radon be reviewed by the Agency's Science Advisory Board (SAB), a brief discussion follows. The radon research program recently has been submitted to the SAB. The Agency's indoor air research program will be submitted for further review by the SAB at the time it is reported to Congress. This program was reviewed by the Indoor Air Quality Research Review Panel of the SAB in September, 1986. At that time the panel was presented with ongoing EPA research in indoor air and a plan for conducting a review of the current state of knowledge in the field. The panel was asked to assess the relevance of current projects and to comment on the adequacy of EPA's proposed "research needs assessment" (RNA). Panel members concluded that the indoor air research program being conducted by EPA was of high quality and had contributed significantly to the overall understanding of indoor air pollution.[1] They recommended that the Agency move forward with its plans to develop an RNA and that the scope of the study be expanded to include areas of research not traditionally associated with EPA such as

---

1 A copy of the SAB report can be found in Appendix A. EPA's detailed response to the SAB report can be found in Appendix B.

the effects of microbial pollutants indoors. Moreover, the panel urged strongly that the Agency develop an indoor air policy and clearly define its program and objectives. This report to Congress is a major step forward in articulating the Agency's position on indoor air.

# CHAPTER I: BACKGROUND

## A. HISTORICAL CONTEXT

When the Clean Air Act was amended in 1970, the air pollution problems of greatest concern to the nation were out-of-doors. The "mounting dangers to the public health and welfare," as described by Congress in Title I, were perceived to be caused by "urbanization, industrial development, and the increasing use of motor vehicles...." Consequently, the law that was intended to protect and enhance the quality of the nation's air resources gave EPA authority to control a wide variety of air emissions sources and air pollutants that contributed to the degradation of ambient air. EPA interpreted the term "ambient" to apply to outdoor air only.

The quality of the indoor air was not mentioned in the law. At that time, except for studies of specialized environments like submarines, space capsules, and the industrial workplace, virtually no scientific research had been done on indoor air quality.

However, in the early 1970s, indoor air pollution received increasing public attention when the Government instituted energy conservation measures. During this time, formaldehyde was identified as the cause of acute irritant reactions, primarily eye and nose irritation and respiratory distress, in individuals living in homes insulated with urea-formaldehyde foam insulation and in mobile homes constructed with large quantities of particleboard and plywood. This led to additional research to assess the types and quantities of air pollutants found in various indoor environments, all of which came to the same conclusion: pollutant concentrations were often much higher indoors than they were outdoors. Furthermore, when high exposure levels were coupled with the fact that most people spend more of their time indoors than outdoors, the risk to human health from indoor air pollution was shown to be potentially greater than the risk posed outdoors.

As the general problem of indoor air pollution was drawing more and more public attention as a potential health hazard nationwide, a particular type of indoor air pollution--radon--was causing immediate concern in particular parts of the country. Epidemiological studies of underground miners had established a link between exposure to elevated levels of radon and the development of lung cancer. In the late 1960s and early 1970s, EPA had investigated homes in Grand Junction, Colorado, contaminated by uranium mill tailings, a byproduct of uranium mining. The elevated radon levels found in those homes led to the issuance of the Surgeon General's guidelines regarding remedial action in houses built on or with uranium mill tailings.

During the 1970s, EPA also investigated instances of elevated radon levels in houses built on reclaimed phosphate mines in central Florida. In 1979, EPA issued guidelines to the State of Florida for remedial action in

existing homes and for new home construction. In 1983, the Agency began to clean up, under the Superfund program, a number of homes in New Jersey that were built on industrial radium waste sites.

National attention was focused on the problem of indoor radon in 1984 when a worker at a nuclear powerplant in Pennsylvania was found to be living in a house that was contaminated by extremely high levels of radon. In that case, the radon was being emitted by the natural soil on which the house was built. Subsequent investigations revealed that thousands of homes in the Reading Prong, a geological formation that runs from Pennsylvania through New Jersey and into New York, were contaminated by naturally-occurring radon. Public concern over the potential health effects of radon exposure, and the realization that such exposures could be occurring over wide areas, led to the establishment of EPA's Radon Action Program directed specifically at the indoor air pollution problem caused by radon.

## B. RESOURCES

In fiscal years 1982 and 1983, Congress appropriated $500K each year specifically to EPA for research on indoor air quality. Eventually, a total of approximately $7 million was appropriated -- including roughly $2 million per year in FY 1984, FY 1985, and FY 1986.[2] Of the monies spent in FY 1984 and FY 1985, approximately $400,000 was spent to conduct research on mitigation technologies for radon. In FY 1986, $1.6 million, in addition to the $2 million for research on indoor air pollution, was appropriated for radon mitigation research. The resources set aside for radon research were supplemented by $200,000 in FY 1984, $310,000 in FY 1985, and $2.4 million in FY 1986 for programmatic activities associated with radon. A detailed list of resources is provided for fiscal years 1984-1986 in Appendix C.

## C. CURRENT EPA POLICY

The Agency's policy with respect to indoor air pollution does not differ from that for pollutants found outdoors--that is, to protect human health from undue risk of exposure to environmental pollutants. The goals of EPA's programs in indoor air pollution and radon are to:

- Identify the nature and magnitude of the health and welfare problems posed by indoor air pollution; and
- Reduce the risk to human health and productivity from exposure to indoor air pollutants.

---

[2] The projects funded with these monies are described in the "Indoor Air Quality Research Plan" prepared by the Interagency Committee on Indoor Air Quality (CIAQ), and submitted to Congress in August 1986.

The strategy for implementing these goals employs the following four approaches: (1) emphasizing non-regulatory actions to address the problem; (2) encouraging State and local governments to play an active role in all aspects of goal achievement; (3) coordinating and encouraging the efforts of other Federal agencies which have responsibility and authority with respect to indoor air; and (4) coordinating Agency activities with the private sector.

While the Agency's program in controlling exposure to indoor radon gas is already well underway (see Chapter 3), we are just now in the process of designing a program which will address those aspects of the indoor air problem which are not directly related to radon and will be the subject of a subsequent report.

## D. CURRENT EPA MANAGEMENT STRUCTURE

The Office of Air and Radiation (OAR) and the Office of Research and Development (ORD) share the responsibility within EPA for developing and implementing the indoor air and radon programs. During the SAB review of the Agency's indoor air research program in September (which excluded the radon program) concern was expressed over the need for strong leadership and a clear internal management structure. In partial response to this concern, a subcommittee on indoor air has been established within the Agency's Air and Radiation Research Committee to coordinate future research efforts with the Agency's policy goals. The subcommittee is co-chaired by representatives from ORD and OAR and reports to the parent committee.

OAR and ORD also have established internal management structures to respond to the SAB concerns. OAR has primary responsibility for developing the Agency policy on indoor air quality and managing the programmatic activities in this area. Within OAR, programmatic responsibility for the overall problem of indoor air pollution has been delegated to the Office of Program Development (OPD).

From one perspective, it would be reasonable to assume that a program specifically targeted to radon would be administered as a subset of an overall indoor air quality program, since many of the issues (e.g., building ventilation rates and exposure times) and much of the research are applicable to both. In fact, EPA considered administering its radon program as a subset of its indoor air quality program, but concluded for the following reasons that there was considerable merit in managing them independently. First, indoor radon is more easily characterized than the more general indoor air pollution problem, and second, the magnitude of the health problems caused by radon have demanded an immediate and ongoing EPA response to reduce exposure.

Because of the unique nature of the radon problem, OAR has assigned internal responsibility for administering the radon program to the Office of Radiation Programs (ORP), which had already developed the technical expertise in this area. The Agency is currently establishing a new division

in ORP specifically to address this problem. Since both the indoor air and radon programs are managed within OAR, the information and experience gained from the radon program has been and will continue to be valuable in guiding the indoor air program as it matures.

ORD has the responsibility for developing the scientific data base to support OAR's programs and to advance the state of knowledge on indoor air pollution, including radon. ORD's research program on indoor air is a multidisciplinary effort spanning several ORD laboratories. To facilitate internal ORD coordination of this program, an individual within the Office of Health and Environmental Assessment has been placed in charge of the program. He reports directly to the Assistant Administrator for Research and Development on this issue. His primary responsibilities include: (1) developing the peer-reviewed RNA; (2) developing a long-range research program which incorporates prior SAB recommendations and the findings of the RNA, and which responds to the policy guidance being developed by OAR; (3) co-chairing the ORD/OAR subcommittee on indoor air; and (4) serving as the principal contact on interagency activities. Support for these tasks is provided through a management structure that includes both laboratory and headquarters personnel.

The radon mitigation research program originally was considered to be a subset of the overall indoor air research program, but is now managed separately by the Office of Environmental Engineering and Technology for many of the scientific and programmatic reasons discussed previously.

## E. CURRENT COORDINATION EFFORTS

Within EPA, offices other than OAR and ORD have responsibilities related to indoor air quality. For example, the Office of Policy, Planning, and Evaluation (OPPE) has the general responsibility of reviewing and evaluating policy developed in the program offices. The Office of Pesticides and Toxic Substances (OPTS) has the responsibility of regulating pesticides and toxic substances, some of which are used indoors and thus may contribute to indoor air pollution. Because of the involvement of several EPA offices, an intra-agency ad hoc task force has been established to help develop EPA policy and program strategy, and ensure that Agency-wide policy related to indoor air quality is consistent.

To provide a mechanism for internal coordination for its Radon Action Program, the Agency has established the Radon Work Group and the Radon Management Committee, which are comprised of staff-level and senior-level management officials, respectively, from the various headquarters and regional offices within EPA. These groups provide advice and guidance to the program and the Administrator on various aspects of EPA's radon program.

Federal coordination is provided through the Committee on Indoor Air Quality. This interagency committee: (1) coordinates research on indoor air quality: (2) provides for liaison and the exchange of information on indoor air quality among Federal agencies and with State and local governments, the private sector, the general public, and the research community; and (3) develops Federal responses to indoor air quality issues. It is

comprised of fifteen Federal agencies, with EPA, the Department of Energy, the Department of Health and Human Services and the Consumer Product Safety Commission as the co-chairs. It is subdivided into nine workgroups, one of which focuses on radon.

The SAB provides a peer review function for EPA research activities related to indoor air quality. The SAB has a separate Radiation Advisory Committee which reviews radiation-related activities, including certain projects within the Radon Action Program.

Finally, Title IV of SARA requires the Administrator to establish two advisory groups. The first is to be comprised of individuals representing Federal agencies concerned with various aspects of indoor air quality. It would appear that the CIAQ satisfies these requirements of Title IV. The second is to be comprised of individuals representing the States, the scientific community, industry, and public interest organizations to assist the Administrator in carrying out the indoor air quality research program. EPA is now considering how best to constitute such an advisory group.

# CHAPTER II: INDOOR AIR POLLUTION

## A. GOALS

The goals of EPA's indoor air quality program are to:

° Identify the nature and magnitude of the health and welfare problems posed by indoor air pollution; and

° Reduce the risk to human health and productivity from exposure to indoor air pollution.

## B. STRATEGY

EPA's program to achieve these goals will be geared toward the identification of significant indoor air quality problems and appropriate mitigation strategies. In those instances where significant indoor air pollution problems are identified, the Agency will select from the following mitigation tools, as appropriate, for reducing human health risks:

° regulation under existing statutory authorities (e.g., TSCA, FIFRA, and SWDA) in appropriate circumstances.

° non-regulatory programs of information dissemination, technical assistance, guidance and training; and

° building state and local government and private sector capability to address indoor air quality problems.

Due to the complexity of the issue, EPA is beginning to adopt a dual approach for achieving these goals. Efforts will focus both on the individual pollutants and products found indoors, and on the various types of buildings in which they are found. Indoor air pollution can be prevented or mitigated by reductions in levels of specific pollutants emitted by specific products. Traditionally, improvements in environmental quality have been achieved by controlling these specific pollutants or sources of pollutants. However, there is another facet to indoor air quality. Indoor air pollution also is a function of the ways in which buildings are designed, operated, and used. Thus, a second way to reduce indoor air pollution is to approach it as a "buildings" problem and to change the ways in which buildings function. EPA's indoor air quality program will attempt to address the problem from both perspectives.

## C. HIGHLIGHTS OF ONGOING INDOOR AIR RESEARCH

The following is a summary of the indoor air research program for FY 1987 grouped by the categories enumerated in Title IV of the Superfund Amendments and Reauthorization Act.

### Identification

The major activity in this area has been to conduct a comprehensive review and analysis of the indoor air pollution literature. This assessment includes the collection of exposure data that will be used to model human

exposure to indoor air pollutants. An additional product of this review is the compilation of an exhaustive bibliography of the indoor air literature with approximately 1200 citations to date. The assessment recognizes the multidisciplinary nature of the indoor problem. With the integration of exposure and health effects data, prioritization of indoor air problems may be established. Integration of engineering, monitoring and health research activities can then provide a research strategy to address specific concerns. Thus, the assessment will guide ORD in developing its long-term indoor air research strategy and plan. Foremost is the need to characterize the nature of indoor air quality problems. Particularly important are (1) the health consequences of existing indoor air quality and (2) the extent to which these problems exist nationwide. The assessment will identify those questions, which, when answered by research results, will allow the Agency to better inform the public about sources of indoor air contamination, the relative hazard that indoor pollution may present and the available options for managing indoor air quality.

An important function of the assessment is the identification of research needs to be addressed by EPA. Additionally, the assessment will point out those research needs that fall more appropriately to other Federal agencies to meet, rather than to EPA. This aspect will enable the Agency to fulfill its responsibility in coordinating indoor air research among the several agencies with concerns in this area.

Source Characterization

Characterization of sources of indoor air pollution provides information on pollutant emission rates and the factors influencing them. Such information is useful in guiding health and monitoring studies and eventually in the control of indoor air quality by source modification. For FY 1987 emphasis is continuing on developing procedures for measurement material sources. Additionally, emission factors and emission models will be developed for organic pollutants from these sources. Both chamber studies and the test house will be utilized in these activities. Among other purposes, the test house will be used to validate the indoor air emission models that are based on the chamber studies of combustion and material sources. Development of an indoor source emissions data base is continuing. This activity is to organize and standardize in a computerized file the data from research studies of emissions from sources of indoor air pollutants. This effort will make such information readily available to the user communities of both the public and private sectors.

Monitoring

The primary focus of research efforts in the area of monitoring is the development of "tools" to better assess indoor air situations and to define the magnitude of the indoor air problem in relation to human health. Hence, research projects will result in improved sampling methodology and other support for studies in residences as well as in office buildings. Several projects involve sampling devices for indoor air: evaluation of a sampler for semivolatile organic components, field evaluation of a sampler for particulates, development of an $NO_2$ detector for personal exposure monitoring, and development of a total indoor air quality sampling package for VOC's and particles. In support of surveys of indoor

air quality, research will be conducted on screening and source use questionnaires, while other work will assess the effectiveness of available screening techniques for indoor pollutants. Other efforts include the completion of a model to evaluate the cost effectiveness of various mitigation strategies. We are investigating the feasibility of a joint study with Canada to develop and demonstrate the methodology for investigating high-risk non-industrial building types ("sick buildings").

Human Health Effects

Sufficient evidence of human exposure to indoor air pollutants is available to demonstrate the need for studies to determine human dose and health effects. Incomplete combustion products such as polycylic aromatic hydrocarbons and many volatile organics from both combustion emissions and building materials are recognized as human or animal carcinogens. Consequently, human exposure to these compounds both individually and in mixtures in indoor air is of great concern. The major combustion emissions of concern are environmental tobacco smoke (ETS) and emissions from combustion appliances (unvented heaters, wood and coal stoves, gas stoves and cooking). In particular, our studies and others have suggested that ETS is the major source of mutagens in indoor air.

FY 1987 studies will continue to characterize the genotoxicity of these combustion emissions and to develop biochemical or biological markers to assess the exposure and dosimetry for indoor organic pollutants. Combustion sources being evaluated include kerosene heaters, gas stoves and ETS. The mutagenicity of the emissions from these sources will be evaluated in laboratory chambers, model homes and pilot field studies. Biochemical and chemical marker methodologies will be developed for the mutagenicity of combustion emissions (e.g., kerosene heaters). Biological markers will be developed for ETS, one such being the physiological excretion of cotinine, a metabolite of nicotine. Neurotoxicology studies include an important replicate experiment to confirm or not confirm the results of a study of Danish homes that found health effects in humans exposed to volatile organic compounds in indoor living environments. In the area of respiratory toxicology, one study is looking for evidence that children and adults exposed to concentrations of $NO_2$ and tobacco smoke which are similar to those experienced in the home might be associated with acute or chronic disease processes.

Control Technologies, Other Mitigation Measures

Mitigation efforts have involved the characterization of particles regarding their physical and chemical characteristics so that the optimum design of filters and electrostatic devices can be evaluated and tested for their cost-effectiveness for indoor air situations. Alternative designs to increase removal efficiency of respirable particles will be explored, developed and tested. Options to be investigated include: new/improved filter materials, pretreatment particle conditioning, and advanced ESP and fabric filter designs. A similar approach is underway for adsorption devices for the removal of organic vapors from indoor air. The research on adsorption will be followed by evaluations of catalytic oxidation and absorption.

Demonstration Methods

With the restructuring of its indoor air research program and the mandate provided by Congress through Title IV, SARA, ORD is developing a long-term strategy and plan for indoor air research. As evidenced by the foregoing summaries of research activities, the resulting program is consistent with the intent of Congress. Because of the nature of the FY 1987 program, to better understand the nature and extent of the problem of indoor air pollution, it is too early to conduct demonstration methods for reducing or eliminating indoor air pollution. Such programs will certainly follow as a consequence of the mitigation efforts described above.

However, a major project is planned for FY 1987 to demonstrate monitoring techniques in preparation for a larger study of the distribution of exposures to indoor air pollutants. This study is the result of the reassessment by ORD of a proposed limited field survey to characterize indoor air quality in the United States. In agreement with the review by the Science Advisory Board, ORD will not conduct the previously proposed survey and has, instead, planned this "demonstration" project. The study will test indoor air quality measurement methodologies and will relate exposure and microenvironmental measurements to those of outdoor fixed sites. The study will be conducted in phases, beginning with a test home, then progressing to a field study of selected homes (less than 10) and then to a larger selection of residences. The results from the study would assess the exposure aspects of indoor air quality, especially addressing the measurements of exposure distributions as related to specific sources.

D. IMPLEMENTATION PLAN

A draft of Volume I of the Research Needs Assessment, the compilation of current knowledge on indoor air, underwent review by a group of some 40 experts assembled at a workshop at Harvard University in January. A final document incorporating their comments and recommendations will be available for review by Congress and the SAB in the near future.

Volume II of the Research Needs Assessment, an identification of information gaps as a result of assessing the current state-of-the-art in indoor air, will provide the guidance for a longer-term research implementation plan. We expect to be able to deliver a preliminary version of this plan to Congress shortly. However, we expect to review these research needs more broadly, sharing them with the other members of CIAQ, the technical/scientific community, and representatives of interested private and public sector groups.

The Office of Air and Radiation is now planning a program to develop and disseminate information and guidance to State and local governments, private sector organizations, and the public. The subsequent report to Congress will include a more detailed discription of activities envisioned for the indoor air program.

# CHAPTER III. INDOOR RADON

Radon is a radioactive gas produced by the radioactive decay of radium-226, which occurs naturally in almost all soils and rocks. Radon is present in the atmosphere everywhere due to its release from radium decaying in the ground. Outdoor radon levels generally are low. Typical indoor levels are usually about five times higher than average outdoor levels, but can be over ten thousand times higher. Exposure to such elevated levels may greatly increase an individual's risk of developing lung cancer. Further, since everyone is exposed to radon in buildings, it is believed that radon substantially contributes to the incidence of lung cancer in the United States. The Environmental Protection Agency and other scientific groups estimate that from about 5,000 to about 20,000 lung cancer deaths a year in the United States may be attributed to radon. (The American Cancer Society expects that about 130,000 people will have died of lung cancer in 1986. The Surgeon General attributes around 85 percent of all lung cancer deaths to smoking.)

While the Reading Prong area of Pennsylvania, New Jersey, and New York is the best known high-radon area in the United States at this time, indoor radon is potentially a widespread problem. Elevated radon levels have been found in houses in many States--not only where suspected geological factors or the presence of uranium deposits suggest that radon might be a problem. Preliminary data indicate that perhaps more than 10 percent of the approximately 85 million homes in the U.S. may have radon levels reaching or exceeding four picoCuries per liter--the level recommended by EPA as a target for corrective action. This level was based on both health considerations and on the limitations of current technology in reducing radon levels below this target level.

## A. GOALS

In response to growing concern about elevated indoor radon concentrations in houses situated on the Reading Prong and those located elsewhere, the EPA Administrator established the Radon Action Program in September 1985. The goals of EPA's Radon Action Program are to:

- Determine the extent of the problem. Information is needed not only on the "hot spots" in the United States, but also on the distribution of radon levels in homes throughout the country.

- Reduce exposure to radon in existing homes. The development and demonstration of cost-effective mitigation techniques will, it is hoped, eventually enable homeowners to correct a radon problem as easily as they might correct a water or electrical problem in their home.

- Prevent radon problems in new housing. By addressing the problem in new construction as well as in existing houses, the potential risk to people who live in new homes can be reduced and consequently, the national average concentration of radon in houses can be lowered.

B. STRATEGY

EPA lacks clear statutory authority to prescribe what homeowners should do about radon. Moreover, it does not appear that a regulatory approach is suitable to deal with this naturally-occurring health hazard. Consequently, the Agency is pursuing its objectives, not by the usual regulatory means (except that it has recently proposed standards for radon in drinking water under the Safe Drinking Water Act[3]), but rather by trying to ensure that the needed technical knowledge exists and that homeowners, contractors, and State and local officials have access to it.

Indoor radon levels can vary greatly not only from community to community, but also from house to house. In addition, the problem areas are widely dispersed throughout most of the country. Therefore, the Agency believes that the primary line of response to the problem should be the State and local governments and the private sector. These groups are in the best position to provide homeowners with the day-to-day support necessary to understand the problem and reduce the risks.

However, EPA and other parts of the Federal government have unique capabilities and expertise to offer the State and local governments and the private sector. Thus, EPA has developed a program that provides for both information development and information delivery. The Agency is developing and disseminating technical knowledge to encourage, support, and facilitate the development of State programs and private sector capabilities in the areas of radon assessment and mitigation. It is acting as a catalyst to bring together the appropriate expertise and responsibilities of Federal agencies, the State and local governments, and the private sector.

The Radon Management Committee (RMC), which is comprised of senior management officials from the various headquarters and regional offices within EPA, was established to provide broad policy advice and guidance to EPA's Radon Action Program and the Administrator. The RMC identified priorities for the FY 1987 radon program, and developed the following consensus ranking of the most important tasks:

1. Identify cost-effective mitigation technology for existing houses.

2. Assist States in developing programs to help citizens understand radon-related health risks and take action to assess and, if necessary, reduce their exposure.

3. Develop information materials that States and private sector groups can use to help citizens and homeowners.

---

3 Volatile radon can be transported to indoor air by drinking water that is derived from some groundwater sources. The mechanisms for the release of radon from drinking water to indoor air include: showers, baths, clothes washers, dishwashers, cooking, and flushing toilets. The average contribution from the drinking water source to indoor air radon levels is in the range of one to seven percent.

4. Promote good practices in radon measurement (e.g., use of recognized methods, proficiency in making measurements).

5. Develop training courses and materials useful for governmental and private sector personnel.

6. Assist States in designing and conducting surveys to identify high-radon areas.

7. Conduct a national survey to determine the distribution of indoor radon levels and identify the factors that influence such levels.

8. Share with States and the private sector all available technical knowledge about radon measurement, mitigation, prevention, and other key topics, and help them learn how to use that knowledge.

9. Identify cost-effective prevention technology for new housing.

10. Reaffirm or revise the Agency's estimates of the health risks associated with radon exposure.

In establishing this ranking, the Management Committee agreed that all ten areas are important in achieving the Agency's goals and should be supported to the extent possible.

The Management Committee also recognized the importance of the contributions of other Federal agencies to the overall goals of EPA's Radon Action Program. Consequently, they recommended that a portion of the Agency's efforts be devoted to working with Federal agencies such as the Department of Energy, the Department of Housing and Urban Development, and the U.S. Geological Survey.

## C. IMPLEMENTATION PLAN

To provide a better focus to its efforts, the Agency's radon program consists of five major elements and objectives:

- Radon exposure and health risk: To identify areas with high levels of radon in houses and to determine the national distribution of radon levels and the associated risks.

- Mitigation and prevention: To identify cost-effective methods to reduce radon levels in existing structures and to prevent elevated radon levels in new construction.

- Capability development: To stimulate the development of State and private sector capabilities to assess radon problems in homes and to help people mitigate such problems.

- Public information: To work with States to provide information to homeowners on radon, its risks, and what can be done about it.

- Federal coordination: To take advantage of the expertise, responsibilities and resources in this Agency, the Department of Energy (DOE), and throughout the Federal government in addressing the radon issue and to coordinate the activities of each Agency to maximize the effectiveness of the overall Federal effort.

The following discussion describes the tasks necessary to meet the objectives of the Agency's indoor radon program. Included in this discussion is a brief outline of the progress made to date on each of the activities and a projection of what remains to be done. A crosswalk between the requirements of Title IV and the activities of EPA's Radon Action Program is provided in Appendix D.

## 1. RADON EXPOSURE AND HEALTH RISK

### (a) Conduct a National Assessment of Representative Structure Types and Geographical Locations

The Agency plans to conduct a national assessment to better define the distribution of radon levels in houses across the country and to determine the national average. Existing information on indoor radon levels is fragmented and is very likely to be skewed because a disproportionate number of measurements have been made in known problem areas, such as the Reading Prong. A determination of the distribution of radon levels throughout the United States is essential in determining the risk to the general population from indoor radon.

A design for the national assessment was submitted to the Radiation Advisory Committee of EPA's SAB in September 1986. They offered the Agency some initial recommendations, and EPA is revising the design accordingly. The SAB's final review is expected to be completed by mid-1987, at which time EPA will make the SAB's final report, along with any Agency comments, available to Congress.

The national assessment is likely to involve 3,000 to 5,000 structures randomly distributed throughout the United States. In its initial recommendations, the SAB stressed the importance of obtaining a high rate of participant return to maximize the value of the survey results. In addition, the cost of the assessment has been estimated to range from $300 to $500 per dwelling. These two factors have been influential in determining the number of houses that will be included in the survey. While the sample size planned will yield a good picture of the distribution of radon levels across the United States, it will be minimally useful in assessing the factors which influence those levels, such as geology and house characteristics.

EPA expects to begin deployment of measurement devices in FY 1988. Devices will be placed in houses for a one year period to obtain the annual

average radon concentration in each structure. The survey and the associated data analyses will take approximately two to three years to complete.

Another important feature in determining public exposure to indoor radon is the concentrations found in schools, office buildings, and other non-residential structures. The Agency's national assessment is devoted to private residences, because they are usually the major sources of exposure. However, EPA plans to look at what data exist for other types of structures and to conduct a feasibility study of what needs to be done to provide an indication of the levels in non-residential buildings. The results of this study will be provided to Congress in October 1987, in the Agency's report to Congress mandated by Section 118(k)(1) of SARA.

(b) Provide Technical Assistance to State Survey Efforts

While it is important to determine the national distribution of radon levels, it is also important to locate areas of particular concern. The Agency considered including this objective in the national assessment, but realized that it would be too resource intensive, and the information would not be available soon enough to meet the demand to identify high-risk areas. Therefore, the Agency designed a program to provide assistance to States in conducting their own surveys. The objectives of EPA's State Survey Program are to: (1) find areas of high indoor radon levels; (2) implement consistent survey methods to assure comparable results; and (3) determine how geology can be used to predict high indoor radon levels. Assistance offered by EPA depends on an individual State's needs, but may include survey design, measurement devices (charcoal canisters), laboratory analysis, etc.

Ten States (Alabama, Colorado, Connecticut, Kansas, Kentucky, Michigan, Rhode Island, Tennessee, Wisconsin, and Wyoming) are participating in the survey program this winter. These ten states were selected, from a total of 21 requestors, primarily on the basis of their ability to deploy measurement devices during the 1986-1987 heating season. Ten is the maximum number of States that EPA can provide assistance to at one time. The Agency expects to eventually provide assistance to the other 11 States who requested it, as well as to any future requestors.

While the State surveys will provide more detailed information in a shorter time period than the national assessment, it will be several years before the majority of surveys are completed, the data analyzed, and the reliability of geological factors in predicting high indoor radon levels are determined. However, data from the first ten States will be available this summer and will be incorporated into EPA's Section 118(k) report to Congress.

The national assessment and the State survey program were designed to complement one another and to maximize the effectiveness of the Agency's resources. Completion of these tasks will provide information necessary to better define the distribution of indoor radon levels across the country, and to identify those areas of the United States in which elevated indoor radon concentrations may be a problem. In addition, data gathered through these survey efforts will be used to determine and characterize the factors which may influence such levels.

(c) Develop Models to Predict the Potential for Structures Built on Certain Land Types to Have Elevated Indoor Radon Concentrations

An important adjunct to the survey efforts to identify high-risk areas is the ability to predict the occurrence of elevated indoor radon levels based on models. One can think of this task as a ladder, with the lowest rung being the ability to predict whether large blocks of land, such as the northwestern portion of a given State, might cause high indoor radon levels. The middle part of the ladder would be the ability to predict whether smaller areas of land, such as individual counties, might have an indoor radon problem. Finally, at the top of the ladder would be the ability to predict whether an individual parcel of land might cause high radon levels in a house built on it. This latter piece of information is the most useful, but also the most difficult to obtain.

The Agency presently has a modest effort underway to identify those geological factors and characteristics which are most useful as indicators of high radon levels. EPA also is conducting some preliminary work on the use of soil gas measurements to predict the radon potential for individual parcels of land. This technique appears promising, but is a long way from being a reliable and accurate predictor of high radon levels. Ultimately, work in the area of hazardous land evaluation should yield a model that can predict, on both a macro and a micro level, the potential for a particular area to cause high indoor radon levels.

(d) Develop Measurement Protocols

Since many radon measurements are now done by commercial firms, it is critical that these measurements be comparable and that the public has some assurance that they are being done accurately. To meet this need, the Agency published standardized measurement protocols in February 1986, for seven of the most commonly-used measurement methods. This document was followed by a protocols applications document in September 1986, which outlines the procedures for determining where measurements should be made in a house and under what conditions. DOE is also pursuing improved measurement protocols.

Protocols are needed to ensure that the new devices being developed to measure radon indoors are used correctly. In addition, further protocol applications are needed for specific circumstances, such as epidemiological studies and radon diagnosis for remedial action. Limited work is beginning in these areas.

(e) Conduct Epidemiological and Other Health Studies to Determine the Link Between Lung Cancer and Radon Exposure in Houses

There are many unanswered questions concerning the health effects of radon. Current risk estimates are based on underground miners; however, there is a strong need to establish a link between increased risk of lung cancer and exposure to radon in a residential setting. In addition, there are questions about the risk to children and the potential synergistic effects between radon and smoking.

Several epidemiological studies are planned to address these questions. Two of the larger studies, sponsored by DOE and the New Jersey Department of Health, are just beginning and will be conducted in Pennsylvania and New Jersey, respectively. It is important to note that preliminary results from these studies will not be available for several years because of the latency period associated with lung cancer. Preliminary results from the eastern Pennsylvania study, conducted by Argonne National Laboratory, will be available in 3-5 years.

The Agency is tracking the epidemiological studies now underway, and is identifying study populations and additional epidemiological research opportunities to assess the exposure of the general population to indoor radon. In addition, EPA and the Nuclear Regulatory Commission are sponsoring a study by the National Academy of Sciences to review all existing available data on health risks from radon. The study report is expected to be published in the spring of 1987.

2. MITIGATION AND PREVENTION

(a) Develop and Demonstrate Cost-effective Mitigation Methods to Reduce Radon Levels in Houses

There are four ways to reduce radon levels in a structure: (1) prevent radon from entering a house; (2) ventilate the air containing radon and its decay products from the house; (3) remove radon and/or its decay products from indoor air; and (4) remove the source of the radon. The Agency is conducting a program to demonstrate these various mitigation techniques.

The results to date have been very promising. Our experience, thus far, indicates that the use of techniques that prevent radon entry by ventilating the radon-laden soil gas from under or around the foundations or from within basement block walls is effective. This approach can reduce radon levels by more than 95 percent, even in houses with very high initial radon levels (greater than 1000 picoCuries per liter). The costs of these techniques are expected to range from $100 to $5,000 per home, with an average of approximately $1,000 per home. The costs of radon reduction methods are expected to decrease as more qualified mitigation contractors enter the market. Thus, indoor radon levels can be reduced substantially at a relatively low cost. Our experience also indicates that the mitigation schemes are very house-specific, and more than one mitigation method may have to be used to reduce radon to an acceptable level in a given house. Finally, methods to prevent radon from entering a house are most effective in reducing extremely elevated levels.

The information gained through research on 18 homes in Pennsylvania contributed to two Agency publications in August 1986: "Radon Reduction Methods: A Homeowner's Guide," and "Radon Reduction Techniques for Detached Houses: Technical Guidance." These publications will be revised in FY 1987 based on additional research in Pennsylvania, New Jersey, and New York.

For the next several years, EPA plans to continue the demonstration program in existing homes in the Reading Prong, and begin demonstrations in States outside of the Reading Prong to gain experience in a wider variety of housing types. In FY 1987, the Agency plans to conduct demonstrations

in up to 110 homes in Pennsylvania, New Jersey, New York, and up to three other States.

Thus far, the demonstration program has focused on active soil ventilation techniques. Most of the houses involved have had high radon levels (greater than 100 picoCuries per liter). In addition, some research has been done on heat recovery ventilators and methods for reducing radon in household water supplies. Research on these techniques will continue, and studies on passive soil ventilation techniques will be initiated. Future work will be directed towards houses with lower concentrations--levels in the 4 to 100 picoCuries per liter range--the range in which most affected houses fall.

To approach the demonstration program in a systematic manner, EPA has developed two matrices that enable the Agency to maximize the use of its resources and ensure that all the key variables in housing and mitigation technology are tested adequately. One matrix has been developed for existing houses and another for new houses. These matrices have been reviewed by the Agency's SAB, which supports their use. Each matrix includes various radon reduction techniques, initial radon levels, house substructure types, important house design features, soil characteristics, and other relevant factors. The cells in the matrix need to be filled with a minimum of five replicates each to achieve the confidence levels that homeowners are likely to want before they install a mitigation measure in their homes. EPA's current estimate is that at least 600 existing homes and 125 new houses will have to be tested to fulfill this objective.

EPA is developing and validating diagnostic protocols that researchers, States, and private contractors can use to determine mitigation approaches in houses. The protocols will also help EPA and others to collect comparable data from those who install and test the effectiveness of radon reduction techniques in houses.

(b) Apply and Evaluate Mitigation Methods

Once mitigation methods have been developed and demonstrated under research conditions in a selected number of houses, they must be more widely applied and evaluated in a large number of varied housing types under conditions likely to be faced by the average homeowner. To meet this need, the Agency has initiated a House Evaluation Program with three objectives: (1) to evaluate the cost and effectiveness of mitigation methods in the private sector; (2) to train State and private sector personnel in diagnosing and mitigating radon in houses; and (3) to provide feedback to the Agency's mitigation demonstration program.

In carrying out the objectives of this program, State personnel, in cooperation with EPA, diagnose a house with elevated radon levels and offer the homeowner several alternative mitigation schemes. In exchange for this service, the homeowner permits the State and EPA to obtain data on radon levels in the homes after the installation of control techniques. Thus, valuable information is gained on the cost-effectiveness of the installed techniques. An important facet of this program is the homeowner chooses whether to undertake the mitigation work, and is responsible for selecting the contractor. This is a significant difference between the house evaluation program and the Agency's demonstration program.

An additional benefit of this project is that it provides "hands-on" training in radon diagnosis and mitigation to State and local governments, and to private sector personnel, and promotes the use of local contractors to conduct mitigation work, thus expanding the cadre of experienced mitigation professionals. It is also expected that many homeowners will attempt mitigation on their own. The results of these efforts will provide information on the feasibility of radon mitigation being conducted by the homeowner, and will serve to better focus public information materials.

The Agency has already evaluated approximately 80 homes in Pennsylvania. During the remainder of FY 1987, EPA plans to evaluate up to another 150 homes in Pennsylvania, New Jersey, New York, and in States that may have identified problem areas through their survey efforts.

(c) Develop and Demonstrate Techniques to Prevent Radon Entry in New Construction

A critical element in reducing the health risk from radon exposure is to prevent radon entry in new construction. This can be accomplished by using specific building techniques. Some research has been conducted in this area by groups outside of EPA. The evidence clearly indicates that it is easier to prevent a radon problem before a house is built than it is to correct it afterwards. Thus, the Agency is designing a program for FY 1987 to conduct demonstrations in up to 25 new houses in New York and other States. The Agency is trying to situate the demonstrations on land that has the potential for causing radon problems and where the developer is willing to build preventive techniques into some of the houses while keeping others of the same design as controls. Generally, EPA will build in passive control measures, but will make it easy for the homeowner to use active soil ventilation techniques should they prove necessary.

The Agency is working closely with the housing industry, particularly the National Association of Home Builders (NAHB), to encourage their interest in this area. As part of a cooperative agreement, EPA and NAHB are putting together a pamphlet on preventive construction methods. This will be eventually followed-up with a technical manual describing in detail various construction practices to prevent radon entry.

(d) Develop Model Building Codes

The only way to ultimately ensure that prevention/mitigation techniques are incorporated into new construction practices is through modifications to local building codes. Florida has already passed legislation requiring the use of certain construction practices in houses built in certain areas of the State. Other States and localities are considering similar action. The Agency is working with the Council of American Building Officials and the three model code organizations to ensure that Agency efforts in the area of radon prevention are reflected in local building codes.

(e) Study Fundamentals and Devices

To assist the field demonstration on radon reduction in new and existing homes, certain aspects of radon mitigation require laboratory research.

The Agency is developing methods to evaluate the effectiveness of certain types of air cleaning systems. This work will have applicability to indoor air pollutants in general, as well as to radon decay products. Additional research needs include tests of sealants and coatings, and the development of standardized specifications for mitigation schemes, such as subslab ventilation systems. These needs, once met, will greatly enhance the development of private sector mitigation capabilities.

3. CAPABILITY DEVELOPMENT

(a) Provide Technical Assistance to the States

The objective of EPA's State assistance program is to encourage self-sufficiency within States as they address radon problems. The approach the Agency has taken is to transfer technical knowledge to State personnel and help them learn how to use it. EPA will show the States how to do the work, but will not do it for them. Similarly, EPA will provide them with technical support services, but will not offer long-term financial assistance. This effort has headquarters, laboratory, and regional components.

The types of assistance EPA provides to States may include:

- Designing and conducting State surveys;
- Hands-on experience in diagnostic evaluation;
- Consultation on development of State programs;
- Analytical services;
- Training courses and informational materials;
- Communications with affected communities; and
- Advice and technical information on radon mitigation.

Many States will require some or all of these types of assistance.

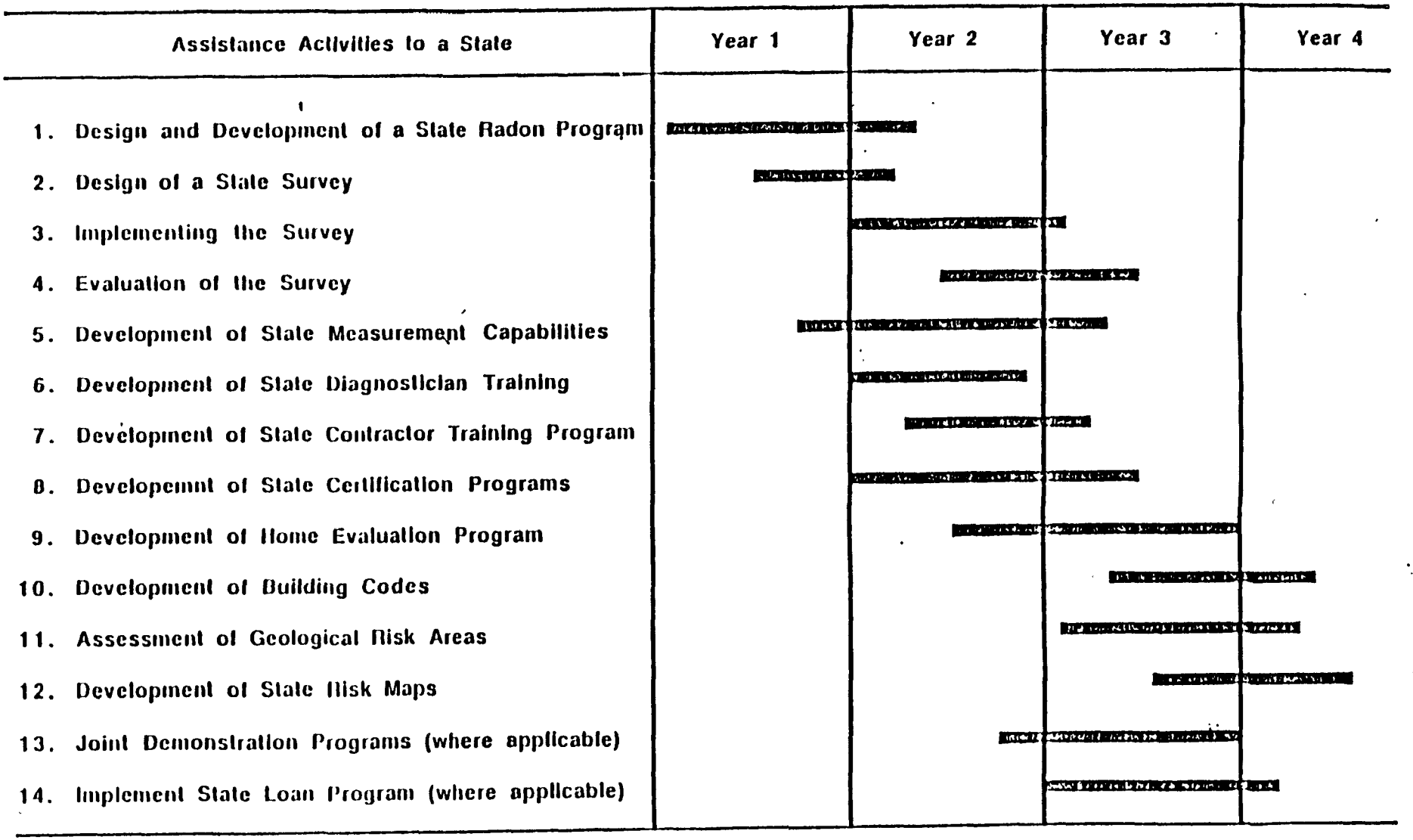
Table I indicates a typical workload for developing capabilities in a State. The tasks range from survey design to implementing a low-interest loan program if a State chooses this option to provide financial assistance to homeowners. Once a State discovers a radon problem, it must develop, in somewhat of a step progression, many of the capabilities described in Table 1. The Agency's experience with Pennsylvania, New Jersey, and New York indicates that States will need EPA assistance for two to five years. EPA currently is targeting resources to develop the types of capabilities indicated in Table I in the States affected by the Reading Prong, but is now beginning to move to States outside that area. It is likely that EPA will be required to provide State assistance over the next five to seven years.

(b) Conduct State Training Programs on Measurement Techniques, Risk Evaluation, and Remedial Methods

There is a great need for training both State and private sector organizations about various aspects of the radon problem. The Agency has developed a "Radon Diagnostician" training course which has been given approximately 20 times to State personnel and their private contractors. The course, which runs 3 days, presents the basics on the physical

TABLE 1

# Typical Workload for Developing Capabilities in a State




These activities may vary from State to State. Overall period of major involvement with a State may vary from two to five years.

characteristics of radon, the available measurement techniques and mitigation methods, and risk evaluation. The Agency is encouraging the States and the private sector to take over this facet of the program. EPA plans to videotape large portions of the course to facilitate its delivery by the States and other appropriate groups, such as universities.

The diagnostician training course has been well-received and has highlighted the need for additional types of training. Since new developments are occurring almost daily in the radon mitigation field, there is a need for a one-day follow-up session to update participants on new mitigation techniques. In addition, there is a need for a longer course (perhaps a week) which would focus on actual "hands-on" mitigation experiences. The target audience primarily would be construction contractors interested in conducting radon mitigation work. There is currently a very limited cadre of qualified mitigation contractors, and demand for their services far outstrips the supply. By designing training courses to be eventually adopted by the States and the private sector, EPA can increase the number of mitigation professionals available to provide remedial services to homeowners.

(c) Implement a Quality Assurance Program for Radon Measurement

To reassure the public that radon measurements being made by commercial firms are accurate, the Agency established the Radon Measurement Proficiency (RMP) program to allow measurement companies to voluntarily demonstrate their ability to measure radon and its decay products. To assist in this effort, DOE shared with EPA its quality assurance facilities at its Environmental Measurement Laboratory in New York. EPA has recently developed the necessary capabilities at its Eastern Environmental Radiation Facility to conduct this program in-house. The RMP program has been quite successful, and several States are considering using it as part of their certification programs.

The RMP program is likely to continue to expand over the next year, with more vendors entering the market. The number of companies entering the market has almost tripled since the inception of the program in February 1986, and it is expected to increase over the next year or two. Therefore, EPA has increased the amount of resources committed to this program. However, at the same time, to conserve these resources, the number of rounds of the program offered have been reduced from four to two because of the large number of participating companies. Although the number of firms may eventually taper off, the need for the RMP program will continue well into the future. The Agency is evaluating whether there are other feasible funding options.

(d) Issue Technical Guidance

Many Agency activities generate technical information that is extremely useful to the States and the private sector. This information must be packaged and distributed in a timely fashion for these groups to benefit from it. In August, the Agency published its "Radon Reduction Techniques for Detached Houses: Technical Guidance." This manual will be revised and

updated in FY 1987. In addition, the Agency is preparing technical guidance for new home construction in cooperation with the NAHB. There will be a continuing need for these types of technical documents as new strides are made in the field.

(e) Establish a Federal Clearinghouse for Information on Assessing and Mitigating Exposure to Indoor Radon

A recent report issued by the U.S. General Accounting Office indicated the need for a Federal clearinghouse on radon.[4] Such a clearinghouse would collect and distribute information and research produced by the public, private, and academic sectors on radon. Because of the increasing volume of data, there is a growing need for a central collection point for information related to health effects, measurement data, radon prevention and mitigation techniques, etc. While the Agency recognizes this need as well, it has had to place a higher priority on first generating and disseminating information to assist the States and the public.

4. PUBLIC INFORMATION

There is a continuing need to work with the States to provide homeowners the information necessary to help them understand and evaluate the radon problem. An effective public information program is an essential component of EPA's approach to indoor radon. Last August, the Agency published two brochures, "A Citizen's Guide to Radon: What It Is and What to Do About It," and "Radon Reduction Methods: A Homeowner's Guide." Both are aimed at helping the general public understand indoor radon. These brochures have been adopted by a number of States and private sector organizations. Similar types of brochures directed at specific audiences or at other aspects of the radon problem are needed to supplement existing materials. The Agency is also working with private groups to develop educational materials or workshops for their members. In addition to these activities, the Agency expects to participate in various symposia, workshops, and public meetings.

5. FEDERAL COORDINATION

There is an active interest on the part of other Federal agencies to evaluate the problem of elevated radon concentrations in homes. The Department of Energy and the Department of Housing and Urban Development (HUD) have particular interest in the effects of radon on the indoor environment. DOE's energy conservation activities are balanced with efforts to assess and mitigate the effect of conservation on indoor radon levels. Further, DOE plans to enhance its radon basic research efforts in 1988 and is devoting an additional $10 million in the areas of health and biological effects and geological studies; EPA and DOE have cooperated in a research project on

---

[4] Indoor Radon Air Pollution, Government Accounting Office. GAO-RDED-86-170, June 1986.

radon mitigation diagnostics. A copy of DOE's Radon Research Program Plan is attached as Appendix E. A draft memorandum of understanding between EPA and DOE on radon research and related technological activities is in its final form. HUD is mandated by statute to ensure that all HUD-assisted projects are located in safe and healthful environments. In this context, HUD is interested in developing inexpensive and effective mitigation techniques for new and existing houses.

These different agency concerns have led to the formation of several forums for the discussion of the indoor radon problem by interested Federal agencies. The CIAQ has a special workgroup to develop a coordinated Federal response to the radon problem. EPA and DOE co-chair this group, which has prepared a document which outlines the indoor radon issue, assesses current Federal research efforts, and identifies priority information needs. These priority tasks are consistent with those identified in this implementation plan.

In addition, the Committee on Interagency Radiation Research and Policy Coordination (CIRRPC), under the Office of Science and Technology Policy (OSTP), is examining the radon issue through its Radon Subpanel, which has reviewed the Federal government's activities on radon. The results of its findings are contained in "Radon Protection and Health Effects" published in August 1986. CIRRPC consists of representatives from 18 Federal agencies and a subcabinet level representative from OSTP. It is responsible for coordinating radiation matters among Federal agencies, evaluating radiation research, and providing OSTP with advice on issues of radiation policy.

APPENDIX A

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D C. 20460

November 5, 1986

OFFICE OF
THE ADMINISTRATOR

The Honorable Lee M. Thomas
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Dear Mr. Thomas:

The Science Advisory Board's Indoor Air Quality Research Review Panel prepared this report in response to the request to undertake a review of the Office of Research and Development's (ORD) plan to assess indoor air research needs. This broad based review focused on research plans, design of a limited field study, and ongoing research.

Although the Agency was not specifically charged with responsibility for indoor air quality under the Clean Air Act Amendments of 1977, it is the Federal agency whose mission clearly relates to this issue. This mission is supported by the recent passage of the Radon Gas and Indoor Air Quality Research Act of 1986, as well as language in the House of Representatives appropriations bills for fiscal years 1984 and 1985. Through its research activities in support of the regulatory work in the Office of Air and Radiation, the Agency has made substantial contributions to the knowledge of the factors determining indoor air quality, and of its effect on human health. Nevertheless, the Panel concluded that while the indoor air research being conducted was of high quality, the research taken as a whole did not constitute a "program" in indoor air quality.

Our major recommendations include: 1) development and adoption of a clear policy statement that indoor air quality is an important and essential component of the responsibility of the Agency, 2) assigning responsibility for the indoor air quality program to an individual of appropriate scientific stature with specific experience in this area, 3) the proposed limited field survey should not be carried out as presented since the resources that it would demand are not commensurate with the scientific information and insights which would be derived, 4) preparation of a relative risk assessment for the more important pollutants (including asbestos, biological contaminants, criteria air pollutants, and toxic chemicals) in order to develop a framework for decision making, and 5) eight general conclusions and recommendations concerning current research on indoor air quality.

In researching and preparing this report, the Panel was pleased with the cooperation and candor of Agency staff in conducting briefings and answering questions.

Thank you for the opportunity to present our evaluation of this program. We look forward to the Agency's response to our report.

Sincerely,

Jan A.J. Stolwijk, Chairman
Indoor Air Quality Research
Review Panel
Science Advisory Board

Norton Nelson, Chairman
Executive Committee
Science Advisory Board

cc: A. James Barnes
Vaun Newill
Craig Potter
Terry F. Yosie

# REVIEW OF THE OFFICE OF RESEARCH AND DEVELOPMENT'S PLAN FOR ASSESSING INDOOR AIR RESEARCH NEEDS

A REPORT OF THE

INDOOR AIR QUALITY RESEARCH REVIEW PANEL

OF THE SCIENCE ADVISORY BOARD

October 24, 1986

U.S. Environmental Protection Agency
Science Advisory Board
Washington, D.C.

## NOTICE

This report has been written as part of the activities of the Environmental Protection Agency's Congressionally established Science Advisory Board, a public group providing extramural advice on scientific issues. The Board is structured to provide a balanced, independent, expert assessment of scientific issues it reviews, and hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency nor of other agencies in the Executive Branch of the Federal Government.

U.S. Environmental Protection Agency
Science Advisory Board
Washington, D.C.

## Indoor Air Quality Research Review Panel

### Chairman

Dr. Jan A.J. Stolwijk, Department of Epidemiology and Public Health, Yale University School of Medicine, New Haven, Connecticut

### Panel Members

Dr. Irwin H. Billick, Gas Research Institute, Chicago, Illinois

Dr. Naihua Duan, Statistician, Rand Corporation, Santa Monica, California

Dr. David Grimsrud, Lawrence Berkeley Laboratory, University of California, Berkeley, California

Dr. Thomas J. Kulle, Research Associate Professor of Medicine, University of Maryland School of Medicine, Baltimore, Maryland

Dr. James Melius, National Institute for Occupational Safety and Health, Cincinnati, Ohio

Dr. James Ware, Associate Professor, Department of Biostatistics, Harvard School of Public Health, Boston, Massachusetts

Dr. Jerry Wesolowski, Air and Industrial Hygiene Lab, California Department of Health, Berkeley, California

Dr. James E. Woods, Honeywell Energy Products Center, Golden Valley, Minnesota

Dr. Cary Young, Electric Power Research Institute, Palo Alto, California

### Executive Secretary

Mr. Robert Flaak, Environmental Scientist, Science Advisory Board, U.S. Environmental Protection Agency, Washington, D.C. 20460

TABLE OF CONTENTS

## 1. EXECUTIVE SUMMARY

As part of a continuing process for reviewing U.S. Environmental Protection Agency (EPA) research programs, the Science Advisory Board's (SAB) Indoor Air Quality Research Review Panel evaluated, on September 3-4, 1986, the Office of Research and Development's (ORD) indoor air research program. This broad based review focused on research plans, design of a limited field study and a review of ongoing projects (see Appendix A for further details on the Charge to the Panel). The Panel was also free to identify other program needs.

The Panel's major conclusions and recommendations are as follows:

- The EPA should develop and adopt a clear policy statement that indoor air quality is an important and essential component of its responsibility. This policy statement should state the broad objectives that are of the highest priority to EPA. Such an indoor air policy statement and program would serve the Office of Air and Radiation in providing the total exposure perspective to the mandated responsibility to assure clean air to the U.S. population. It would also more clearly define the policy and program goals toward which the research is directed.

- An effective Indoor Air Quality Program must be multi-disciplinary and thus needs to build on a framework which is common to all participants, with clearly recognizable goals. In view of the widespread interest in indoor air quality, and the wide range of clients, it is important that this framework for decision making be understandable and clearly relevant. The most effective common reference point would be a relative risk assessment for the more important pollutants (including asbestos, biological contaminants, criteria air pollutants, and toxic chemicals).

- The Panel unanimously concluded that the proposed limited field survey should not be carried out as presented. The resources it would demand are not commensurate with the scientific information and insight which would be derived. The relevance of the goals was not discussed and presented; the connection with other surveys of various types, completed or currently ongoing, was not established; and the design seemed to be based more on available methodologies than on a clearly perceived goal of the utility which the results would be likely to achieve. A more clearly defined set of objectives might be achievable at a much reduced level of effort. The statistical design, the measurement methodology, the quality assurance were all considered scientifically adequate. As an alternative to the proposed field study, a small field trial of nine residences in the Research Triangle Park (RTP) area of North Carolina, and of nine residences at a remote location, would present a cost effective opportunity to test the feasibility, of such a survey, as well as some of the variance to be expected.

- The Panel reviewed current indoor air quality projects, limiting itself to the relevance and balance of the projects. The Panel reached the following general conclusions and recommendations:

  - Existing work is biased heavily toward residential (single family) environments. The EPA should focus a reasonable amount of attention on occupants of commercial and public sector/public access buildings.

  - Responsibility for indoor air quality implies that areas that are not traditionally addressed in ambient air quality programs, such as radon, asbestos, and microbials, should be covered by coordinated research, intra-murally or extra-murally.

  - The EPA should more carefully articulate how it plans to integrate work carried out by other public agencies and private organizations into its own research program.

  - Building design, construction and operation are essential factors in indoor air quality. The EPA should develop some in-house competency in these areas which complements that present in other agencies.

  - The EPA should state what efforts are being undertaken to follow up on the approach based on a single unconfirmed study (by Mølhave) on the effects of mixtures of large numbers of volatile organic chemicals (VOC) in very low concentrations.

  - Monitoring research which does not have immediate policy relevant results should be regarded as less policy relevant than research aimed at source characterization and control, or research aimed at measuring health effects of exposures.

  The Panel has confidence in the investigators and the EPA staff, and concludes that in the presence of clearly stated Agency policies and a suitable administrative structure, they will produce an excellent program.

- Responsibility for the indoor air quality program should be assigned to an individual of strong, proven leadership who has appropriate scientific stature and specific experience in this area, who would devote full time attention to the program and to the implementation of a research needs assessment. The leadership of the program and the administrative structure should promote multi-disciplinary cooperation in the conception, initiation, and execution of projects and to the dissemination of the information obtained.

## 2. INTRODUCTION

The U.S. Environmental Protection Agency has, for a number of years and on a limited basis, supported and carried out research on factors affecting indoor air quality. Much of the initial efforts addressed criteria air pollutants and how indoor concentrations related to outdoor concentrations. A number of events, observations and insights have served to make air quality in the indoor environment a more salient public health issue. Time budget studies conclude that a very large part of the twenty four hour day is spent in indoor environments. Other studies showed that there are many important sources of air pollutants inside buildings, and the rise in the price of energy in the decade of the 1970's changed the way buildings are constructed and operated. Studies in Western Europe, Canada and the U.S. demonstrated that for many pollutants and in many locations the major fraction of the total population exposure to air pollutants may occur indoors, and for many of these pollutants, such as environmental tobacco smoke, nitrogen dioxide, volatile organic chemicals and radon, the concentration indoors is often much higher than outdoors. These, and other developments, have led to a greatly increased public awareness of indoor air quality issues.

The EPA was not specifically charged with responsibility for indoor air quality under the Clean Air Act Amendments of 1977, but it is the Federal agency for which indoor air quality is closest to its central mission. Congress considers EPA as the lead agency for indoor air quality. Other Federal agencies which have programs and responsibilities in this area, such as the Department of Energy (DOE), the Consumer Product Safety Commission (CPSC), and the Department of Health and Human Services (DHHS), are represented in the interagency Committee on Indoor Air Quality (CIAQ), and they recognize the central position of EPA. It important that the ongoing coordination between these agencies continue.

Through its research activities in support of the regulatory work in the Office of Air and Radiation, EPA has made substantial contributions to our understanding of the factors determining indoor air quality, and of its effect on human health. More recently, research activities have included projects specifically supported by Congressional appropriations for indoor air quality research. The Agency has a number of capable and proven investigators who also have experience in managing and administering extramural research efforts. The CPSC, DOE and DHHS also conduct, support and administer research work of high quality on special aspects of indoor air quality.

## 3. NEED FOR AN EPA POLICY STATEMENT ON INDOOR AIR QUALITY

It is understandable that EPA has moved slowly toward defining its role in improving indoor air quality for the nation. At the time of the formation of the Agency, the relative importance of indoor air quality was not yet recognized. The realization of the importance of indoor air quality in protecting and advancing public health and welfare developed only gradually, and the Panel believes this realization is still growing.

Another reason for the slow development of an indoor air quality policy stems from the clear difference in strategy for the control of ambient (or outdoor) air pollutants compared to indoor pollutants. For ambient air, the most effective strategy is regulatory, while for indoor air quality a very different strategy may be required. One possible strategy for indoor air pollution control is to increase understanding through well-coordinated and designed research, followed by dissemination of this information to individual householders, architects, building managers and organizations that have an interest in or responsibility for the quality of indoor air in residences and public access buildings. Since neither individuals nor such organizations can effectively do all the research required to develop guidelines and control methodologies, this type of information and guidance would help to reduce risks to public health from indoor air quality by helping them make appropriate and well informed choices.

The EPA will continue to experience difficulty in establishing a viable and stable basis for assessing research needs and arriving at efficient decisions on research priorities, schedules and resource allocations, in the absence of a clear definition of the indoor air quality program and its objectives. To improve their effectiveness, EPA researchers must know what specific EPA policies and objectives their research is designed to address.

Although it is understandable that EPA policy on indoor air quality was not easily formulated nor quickly adopted in the past, the Panel recommends that EPA develop such a policy and state its high priority for the nation. Supporting this need is the continuing Congressional direction provided in House of Representatives appropriation bills for fiscal years 1984 and 1985, and the Radon and Indoor Air Quality Research Act of 1986 which is specific to EPA's role and responsibility for indoor air quality and radon research. Such a policy statement can provide integration to EPA's research and other program activities by ensuring that the research program and policy goals are jointly planned.

## 4. REVIEW OF ORD'S PLAN FOR DETERMINING FUTURE RESEARCH NEEDS ON INDOOR AIR POLLUTION

In assessing ORD's plan for future research needs the Panel considered the documents submitted, and presentations by EPA staff.

A scientifically effective indoor air quality research program must be a multidisciplinary one that builds on a framework which is common to all participants, with clearly recognizable goals. In view of the widespread interest in the area of indoor air quality, and the wide range of clients, it is important that this framework for decision making be understandable and clearly relevant. The most effective common reference point would be a relative risk assessment for the more important pollutants (including asbestos, biological contaminants, criteria air pollutants and toxic

chemicals). An example of the output of such an effort would be a table which in one column would list the factors in the indoor atmosphere that are considered important. The next column would list for each of the pollutants the 10, 50 and 90 percentile concentrations as encountered in indoor measurements, and the corresponding outdoor concentrations, with time-weighted exposures. The next column would contain the best estimate of the adverse health effects associated with the observed exposures for each pollutant. The final column would give, again for each pollutant, the total estimate of the incidence of these adverse health effects in the whole U.S. population associated with the exposures derived from previously described columns.

The EPA has not made such estimates in the past, but it should recognize that they will indicate a number of uncertainties and areas of inadequate knowledge. The construction of such a table will require coordinated input from all the disciplines now involved, and should be refined and updated as new information emerges. This table can also clarify which factors are least known or understood, and allow for comparisons of the relative impact on public health and the level of effort necessary. The Panel recommends that EPA staff directly undertake this assessment and not assign it to outside contractors, in order that internal competence improve and that the experience gained will be of maximum direct benefit to the program.

Over the years, such a table should also represent the clearest demonstration of progress that occurs in research and development and in the dissemination of this progress. The Panel knows that efforts have already begun to construct such a table which would also serve to present the best estimate of the current state of knowledge. It would also be useful to incorporate estimates of that fraction of the total population exposure which stems from the outdoor environment. Somewhat similar exercises have derived from the European Regional Office of the World Health Organization, EURO Reports and Studies 103 (1986): "Indoor Air Quality Research".

Finally, the construction of a table which constitutes the generally accepted state of knowledge and its formal dissemination as a basis for research policy decisions will assist in the more effective integration of interagency programs. It will also help to attract extramural investigator-initiated research proposals which match with Federal program needs. It will clarify to Congressional committees the status of current and future research activities.

## 5. REVIEW OF PRELIMINARY PROPOSAL FOR A FIELD SURVEY

The Agency presented the Panel with a preliminary design for a field study that is intended as a pilot for a much larger study in the future. The proposal recommends obtaining a large number of observations in residential environments through physical monitoring and through questionnaire responses from the occupants. The announced objective is to test the hypothesis that

the concentration of indoor air pollutants does not significantly vary in residential environments in different regions or seasons. The proposal specifically states that the study will

> "...address the magnitude of possible factors affecting the distribution of selected indoor pollutants in U.S. residences. This study will emphasize measurements for Volatile Organic Chemicals (VOC's), Semi-Volatile Organic Chemicals (SVOC's), and combustion products including particles (mass and chemical composition) and $NO_2$. The resulting data will be used by EPA in designing future Indoor Air Quality Surveys."

The overall design incorporated two phases. In Phase I, EPA would study nine homes near Research Triangle Park, N.C. with a similar cluster of nine homes studied in or near Gaithersburg, MD. The main purpose of Phase I is to test monitoring and survey instruments. In Phase II, EPA would select two cities. Current planning focuses on Baltimore, MD and Chattanooga, TN. In each of the two cities, EPA would monitor during each of four seasons, in four different ten home neighborhood clusters, for a total of 2 x 4 x 4 x 10 residences. The neighborhood clusters will be chosen randomly from the four quartiles of census derived housing values or from census derived income levels. Within a neighborhood cluster 10 homes would be chosen randomly. The measurement program presented concentrated on VOC's and SVOC's, particulates, $NO_2$, formaldehyde, water vapor, temperature, air exchange rate and nicotine by passive sampling. In addition, EPA plans to carry out screening interviews, baseline interviews and occupant diaries to capture building characteristics and occupant behavior.

The Panel did not possess sufficient information at the time of the review to conduct a detailed evaluation of the technical details of the design, although the Panel commends the Agency for its continuing efforts to use sound statistical practices in the design of surveys. It is evident that the instrumentation is close to, or at, the state of the art level and that EPA will require field validation for some of the methodology.

The major weakness of the proposal is not in the technical design, or in the ability to carry out the design, but in the scientific justification for planning and carrying out a study of this size and cost without demonstrating, or discussing the justification for, its need and how the results would be used. The Panel also found that the number and detail of secondary objectives were overstated and that these objectives could not be met. The Panel noted that EPA has obtained data of a somewhat similar nature in the Total Exposure Assessment Methodology (TEAM) studies. The methodology appears to derive in considerable part from the experience gained in TEAM studies. The TEAM results were not used in any observable way to anticipate the results in the proposed new survey or to assess the qualitative and quantitative variance which could be expected. An analysis and interpretation of the TEAM results along the lines of the planned survey was not evident and would be most instructive.

The Panel unanimously agrees that the field survey proposal should not be carried out as currently presented. The justification presented was not commensurate with the information and insight that EPA would obtain. The relevance of the goals was not discussed and presented; the connection with other surveys of various types, completed or currently ongoing was not established; and the design seemed to be based more on available methodologies than on a clearly perceived goal on the utility which the results would be likely to achieve. A more clearly defined set of objectives might be achievable at a much reduced level of effort.

The Panel concludes that a small field trial of nine residences in the Research Triangle Park area, and of nine residences at a remote location would present the opportunity to test the feasibility, as well as some of the variance expected. It also believes that such an effort would contribute to the building of confidence and competence, especially if EPA staff took an active part in the undertaking.

## 6. REVIEW OF ONGOING RESEARCH PROJECTS RELATED TO INDOOR AIR QUALITY

The Panel reviewed ongoing research projects in the areas of monitoring, source characterization and control, and health effects. The charge to the Panel did not include a detailed evaluation of all of the projects but, rather to comment on the balance, coherence and objectives of the overall program.

In each research area the Panel found that projects are designed and executed with competence and dedication. The scientific and technical soundness, however, is not matched by coherence, clarity or the relative importance of the overall goals. The investigators could not be expected to produce spontaneous coordination, or to develop coordinated objectives without clear policy guidance.

The existing research program currently consists of a collection of projects with few linkages between them. In reviewing this ongoing program, the Panel reached the following conclusions:

- The balance of concern is still biased heavily toward residential (single family) environments. The EPA should focus a reasonable amount of attention on occupants of commercial and public sector/public access buildings. A large number of Americans spend about equal amounts of time in these two environments.

- Responsibility for indoor air quality implies that areas that are not traditionally addressed in ambient air quality programs, such as radon, asbestos, and microbials, should be covered by coordinated research, intra-murally or extra-murally.

- The EPA should more carefully articulate how it plans to integrate work carried out by other public agencies and private organizations into its own research program. Even studies done within EPA by another laboratory other than those located at RTP do not appear to be integrated into new plans. There appears to be a tendency to start de novo projects, rather than building on what is already known

- Building design, construction and operation are essential factors in indoor air quality. Although these areas of expertise exist in several other Federal agencies, the EPA should develop some in-house competency in these areas which complements that present in other agencies. This is supported by the recent Radon Gas and Indoor Air Quality Research Act of 1986.

- The EPA should state what efforts are being undertaken to follow up on the approach based on a single unconfirmed study (by Mølhave) on the effects of mixtures of large numbers of volatile organic chemicals (VOC) in very low concentrations. The Agency should also state what efforts, if any, are being considered to replicate or otherwise confirm this work.

- Monitoring research which does not have immediate policy relevant results should be regarded as less policy relevant than research aimed at source characterization and control, or research aimed at measuring health effects of exposures. Both of the latter can produce results that are immediately usable, and the Panel finds that the flow of resources does not correspond to that relevance. Having clearly stated policies and objectives is likely to bring about changes in these patterns.

The Panel has confidence in the investigators and the EPA staff, and concludes that in the presence of clearly stated Agency policies and a suitable administrative structure, they will produce an excellent program.

## 7. PROGRAM MANAGEMENT

There is a need for a management structure which can both provide the leadership and be held accountable for the clear definition and implementation of research objectives, and a manager who can nurture, guide, and coordinate the clearly very capable human resources and material support dedicated to the indoor air quality program.

Responsibility for the indoor air quality program should be assigned to an individual of strong, proven leadership who has appropriate scientific stature and specific experience in this area, who would devote full time attention to the program and to the implementation of a continuing research needs assessment. The administrative structure, and the leadership of the program should promote multi-disciplinary cooperation in the conception, initiation, and execution of projects, through to the dissemination of the information obtained.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG 15 1986

OFFICE OF
RESEARCH AND DEVELOPMENT

MEMORANDUM

SUBJECT: SAB Review of ORD's Plan for Assessing Indoor Air Research Needs

FROM: Scott R. Baker
Special Assistant to the Assistant Administrator
for Research and Development (RD-672)

TO: Terry F. Yosie
Director
Science Advisory Board (A-101)

The Office of Research and Development is pleased to have the Science Advisory Board consider EPA's plan for assessing indoor air research needs. The plan is in a formative stage. While substantive details of the its conten have not yet been identified, a review at this stage is timely because it allows us to obtain broad, conceptual, scientific advice early in the process, when flexibility and opportunities for accommodating constructive opinions are greatest. We would like to outline for the Panel our perception of the review's purpose, our needs from the Panel, the specific issues that are importa for the Panel to address to help us proceed effectively, and the steps we are taking in planning the Agency's future indoor air research program.

Purpose of the Review

ORD is seeking SAB opinion in three areas:

(1) Scientific advice on the approach that ORD proposes to take in carrying out its assessment of future research needs;

(2) Advice on ORD's preliminary design for an exploratory field study;

(3) Review of ongoing projects that are considered to be influential in the design of the future research plan.

For the past three years, ORD has had a focused research program to addres fundamental questions about the magnitude of the indoor air pollution problem Appropriately, after this initial phase, ORD has now begun an assessment of t current state of knowledge to identify critical gaps about exposures to indoc pollutants, their potential health effects, sources, and possible mitigation measures in all types of buildings. On the basis of the assessment, ORD will refocus its research program to provide greater disciplinary balance and enha relevance to any anticipated Agency decision-making. ORD will simultaneously carry out a limited field study to obtain selected data that will more clear illuminate major gaps in knowledge.

This direction for EPA's indoor air research program has the support of the interagency Committee on Indoor Air Quality, EPA program and policy offices, and Congressional staff. However, all parties agree that before ORD commits its resources fully to this approach, it should seek the advice of scientific experts in the field, including that of the SAB. At the same time, it will be useful for ORD to receive scientific advice from the SAB on the utility of research projects currently underway (or planned at EPA) that might be expected to contribute significantly to the foundation of ORD's future research plan.

Scope of the SAB Review

(1) Scientific advice on the plan for conducting a research needs assessment - ORD will present to the SAB Panel a framework describing how it intends to carry out its assessment and will specify the data bases that will be examined. We would like the SAB Panel to offer its advice on the proposed approach to assessing the gaps in scientific knowledge, including the adequacy, individually and as a whole, of the data bases that will be used in the assessment of research needs. In our desire to conduct a thorough assessment, we are particularly concerned about balance: whether or not we have identified for inclusion in the assessment all appropriate issues; and whether or not we have properly framed the issues to be considered. In this context, it is important that the SAB advise us on the appropriateness of (1) including the following issues in our assessment, individually and on the whole, (2) including any additional issues, and (3) our rationale for characterizing each issue as we have done, recognizing that certain elements were deliberately included or excluded. We are not asking the SAB to advise us on the position EPA should adopt on each issue; to do so at this time would preempt the analytic process that we expect will ensure a product of high scientific quality.

Issues for the Research Needs Assessment

- Selection of chemicals for consideration in the assessment
- Monitoring research
  - Balance between private residences and commercial (public access) buildings
  - Balance between indoor air exposure and total exposure
  - Balance between microenvironmental studies, personal monitoring, and ambient monitoring
  - Identification of needs for development of chemical class-specific monitoring methods.

- Health research
  - Balance of attention to products of combustion, side-stream cigarette smoke, volatile organic compounds (individually and in complex mixtures)
  - Appropriate health-related endpoints to consider in an indoor air research program, including cancer, respiratory effects neurotoxicological effects, and other unknown classes of effects
  - Appropriate exposure scenarios, including chambers, test houses, and field/epidemiology studies.
- Source characterization
  - Appropriate methods to enhance understanding of sources, including chambers and field-level test houses
  - How to determine the role of source characterization in conducting health risk assessments on indoor air pollutants
  - Alternative approaches for ranking sources for testing.
- Control technology
  - Determining cost-effective methods for ensuring good indoor air quality.
- Overall
  - Balance between hazard assessment, exposure assessment, source characterization, and risk mitigation strategies to ensure a proper interrelation between risk assessment and risk management
  - The markets to which the outputs of the future program should be oriented, including consumers (for public decision-making), states and municipalities, regulatory programs, and private-sector manufacturers.

The Office of Air and Radiation (OAR) has recently initiated a policy coordination and development process for indoor air within EPA. This process involves extensive participation by ORD and the policy and program offices within the Agency. As part of this process, OAR will soon undertake a problem characterization study on indoor air. This study is being designed to provide an overview of the problem and to formulate issues around which policy options can be clearly defined. OAR is now developing the central questions that will form the basis of this overview study, and will circulate them within the Agency for review. It is anticipated that these questions will be available to the SAB prior to its meeting for information purposes only. It is intended that the questions lend perspective to the SAB in its review of ORD's activities.

(2) Design of a limited, exploratory field study - There are at least two major uncertainties about indoor air pollutants that ORD believes could be resolved by a limited field study: whether there are regional differences among indoor air pollutant emissions from consumer products found in homes; and whether seasonal differences of product use and exposure exist. The hypothesis is that the distribution of consumer products does not vary sufficiently across the U.S. to cause regional and seasonal differences in indoor air concentrations. This hypothesis will be tested in the limited field study. In addition, this study will serve to test much of the monitoring methodology and technology that has been developed over the past several years. Before embarking on a detailed design for such a study, ORD is seeking SAB advice on a preliminary study designed to address these issues. Specifically, we would like to know the SAB's views on the likelihood of the proposed design providing an adequate test of the hypothesis.

(3) Review of ongoing and planned studies

- In expectation that the indoor air problem would receive increasing priority, ORD has been conducting research to improve methodologies These projects have spanned the range from development of methods for source emission testing, to methods for monitoring and health assessment. We will present to the SAB a brief overview of the monitoring, health, and engineering components of the indoor air program and greater detail on certain studies. While they are part of an integrated and coherent indoor air research program, th individual studies taken alone represent important methodological investigations that have been conducted by individual EPA researchers and which will allow us to fill critical gaps in our understanding of indoor air pollution.

  ORD would like the SAB to comment on the relevance of these studie to the proposed plan for assessing research needs. In keeping wit the concept of SAB reviews of Research in Progress, we would value advice on whether we are "doing the right research" in contrast to "doing the research right."

To assist you in preparing for the meeting, we have attached three document that will be the basis for presentation and discussion:

(1) A status report of ORD's indoor air research program. Please consid the sections on source characterization, monitoring methods developm field studies, and health as background information for the discussi of ongoing studies;

(2) A document outlining the proposed approach to the research needs assessment; and

(3) A description of the preliminary design for a limited field survey.

As is customary, the Panel may choose to consider additional issues for discussion. We look forward to engaging in a productive dialogue with the Panel. We would be pleased to discuss our three requests with any Panel members prior to the meeting. Thank you for assisting us in this activity.

Attachments

cc: Gerald G. Akland (MD-56)
Donald J. Ehreth (RD-672)
Elissa Feldman (RD-672)
Robert A. Flaak (A-101F)
Judith A. Graham (MD-51)
David Maye (MD-56)
Courtney Riordan (RD-680)
Charles Rodes (MD-56)
William G. Tucker (MD-54)
Lance Wallace (RD-680)

APPENDIX P

DRAFT

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

THE ADMINISTRATOR

Dr. Jan A.J. Stolwijk, Chairman
Indoor Air Quality Research Review Panel
Science Advisory Board
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Dr. Stolwijk:

Thank you for your letter of November 5, 1986, containing the Indoor Air Quality Research Review Panel's review of the Agency's plan to assess indoor air research needs. We appreciate the timely manner in which this Panel of the Science Advisory Board (SAB) undertook this review and submitted its report. You succinctly summarize in your letter the substantive conclusions and recommendations of the report, some of which we have already implemented.

We recognize that an Agency policy statement on indoor air is needed, both to establish a purpose and direction for its indoor air program and to guide the Agency's research in support of this program. We believe that Title IV - Radon Gas and Indoor Air Quality Research contained in the recently passed Superfund Amendments and Reauthorization Act of 1986 clarifies our Congressional mandate to conduct indoor air research and to establish an indoor air program. This combined action will make clear that our mission includes assessing the potential harm to the public from indoor air pollution. In addition, the Agency's studies now show the important contribution of indoor exposure to total human exposure to air pollution.

Within the Agency's air research program over the past few years, we have investigated the potential effects from indoor exposure to certain air pollutants. These have included carbon monoxide, oxides of nitrogen, and dust (especially dust containing lead particles). While these efforts have buttressed our major research supporting regulatory activities, they have emerged as a major research area in themselves. As the results of this enlarged research activity become evident, we will begin to factor in the contribution of indoor air pollution to total human exposure when we develop our strategies for outdoor air regulations and for regulations in other areas for which we have statutory authority. To adequately fulfill its mission of protecting and enhancing the Nation's air quality, the Agency must address the potential benefits of reducing exposure to indoor air pollution.

The EPA indoor air program will focus on sharpening the public's awareness of indoor air problems. At the center of this effort will be an Agency-directed research program to provide the information necessary to help us communicate to the public a basic understanding of potential indoor air problems and possible solutions. Private sector and other public sector institutions can be expected to play essential roles in developing and distributing the information necessary to improve and protect indoor air quality. I have delegated to the Office of Air and Radiation (OAR) the responsibility for developing the Agency's policy on indoor air quality. OAR will develop and implement the specifics of the policy while the Office of Research and Development (ORD) will provide support with a research program attuned to the needs of the policy.

A key recommendation in your letter suggests that an effective indoor air quality program must be multidisciplinary and should build on a framework common to all participants. Even before the SAB review, the Agency had begun an effort to assess the available information on indoor air. As a result of your recommendation, that assessment will be expanded to ensure that it identifies the multidisciplinary nature of the indoor air issue. The Research Needs Assessment (RNA) that ORD plans to produce for the Agency's indoor air program will consist of two volumes: the first will compile and synthesize the information on indoor air quality; the second will describe the research plan that the Agency will implement to address the issues raised in the first volume.

The primary value of performing a multidisciplinary needs assessment will be to enable integration of effort among the engineering, monitoring, and health laboratories, to address specific concerns that have been identified, and reconcile any duplicative research activities.

Foremost in our planning at this time is the need to characterize the nature of indoor air quality problems. Particularly important are: 1) the health consequences of existing indoor air quality; and 2) the extent to which these problems exist nationwide. A strategy for accomplishing this characterization is emerging from our assessment. One approach under consideration is one that is health-based; i.e., to investigate the sources of those pollutants causing health effects. Once potential sources of unhealthy indoor pollutant levels are identified, a comprehensive program can be developed for determining the origins of indoor air pollution problems and for correcting these problems with effective control techniques.

Using a health-based approach that focuses on sources has several attributes. Identifying sources of concern allows for quick implementation of mitigation measures. This approach also allows for prioritization by source category within budgeted resources. However, such an approach calls for a multidisciplinary effort that is not easily accomplished within the highly specialized scientific community we have today.

Through our current assessment activities, we are striving to identify those questions which, when answered by research results, will allow the Agency to better educate the public about available options regarding indoor air quality. Individual homeowners (as well as designers, builders, manufacturers and maintenance professionals) will be made aware of the sources of contamination, and the relative hazard that indoor pollution may present, e.g., that associated with improper usage and storage of chemicals. We have already produced a report aimed at this audience, Guidelines for Monitoring Indoor Air Quality, which summarizes current monitoring methods. Other benefits of this report include new methods of assessing problems, the refinement and rethinking of monitoring techniques, the definition of health parameters affected, and the identification of specific populations at risk. Means to avoid or mitigate potential problems can be described, so that affected persons can make intelligent choices regarding how to minimize the level of contamination to which they are exposed.

A very definite conclusion of your review is that our proposed limited field survey should not be carried out as presented. We agree, after considering your advice, that the proposed limited field survey should not be conducted addressing the stated objectives. With the emergence of EPA's program for improving indoor air quality, a more effective effort will include, among other actions, directing monitoring resources toward developing the "tools" to better define the magnitude of the indoor air problem in relation to human health. An integrated research effort to replace the reviewed survey is under discussion by the laboratories at Research Triangle Park. As suggested, it would be designed primarily to test the adequacy of the methodology. This would be an in-house activity as much as possible to minimize cost, build staff confidence and experience, and provide for real-time corrective measures.

Your recommendations concerning our current indoor air quality projects are also helpful. We concur that we should focus our indoor research on those settings which provide the greatest degree of exposure to the public. Commercial- and public-access building microenvironments are second only to residences in this regard. In our 1982-83 indoor air program, we studied 10 such buildings, including schools, hospitals, homes for the elderly, and office buildings. In our planning for indoor air research (for FY-87 and beyond) we are increasing attention to nonresidential settings. Of course, our studies on measurement methods, material source characterization, and indoor air quality control are applicable to both residential and non-residential situations. Our clinical studies of health responses to VOCs were triggered by the "sick building syndrome," a phenomenon most often connected with office buildings.

Also regarding our current indoor air activities, you recommend that our research program should cover areas not traditionally addressed in ambient air quality programs, such as radon, asbestos, and "microbials." The specific areas of radon and asbestos are effectively managed by separate programs within EPA. We have previously not highlighted these areas within the indoor air program because of the distribution of program resources. We will make a more concerted effort to factor these pollutants into the program, in concert with existing programs. The Agency has only limited expertise in addressing

"microbials" but recognizes that this area must be included in future planning. We can utilize existing expertise in other Federal agencies, such as CDC and NIOSH, where work in this area has been ongoing.

Another recommendation of the SAB is that the Agency carefully articulate how it plans to integrate work carried out by other public agencies and private organizations into its own research program. As described earlier we are drafting an assessment of the current knowledge of indoor air pollution. Using this document, EPA will develop a long range research program to provide needed information identified in the assessment. Upon review of this assessment and the resulting research plan by both the SAB and the public, it will be apparent that EPA has reviewed and considered the research efforts of other Federal agencies and the community at large. Such review will be an ongoing effort and we will continue to integrate our research plans with the indoor air research activities of other institutions. We will also be more explicit in our planning documents regarding the integration of research by other groups.

A further recommendation of the SAB is that the Agency develop in-house competency in the areas of building design, construction, and operation. While we rely heavily on the expertise of others (most notably the American Society of Heating, Refrigerating and Air Conditioning Engineers and the Department of Energy), we realize the need for in-house competency in this area. Our radon mitigation research program is developing staff knowledge in residential design, construction, and indoor pollutant dynamics. As our experience grows in indoor air source characterization, pollutant modeling, public building investigation, and pollutant control, we will acquire the kind of expertise that you recommend.

One recommendation dealing particularly with our health effects research suggests that the Agency describe its follow-up of the approach based on the Mølhave study concept. Mølhave and his colleagues have explored the effects of controlled exposure of humans to complex mixtures of volatile organic compounds (VOCs). Results of this study have been published in the peer-reviewed literature and suggest that low level VOC exposure in amounts comparable to concentrations found in new construction Danish homes produced memory impairment and sensory irritation in subjects known to be sensitive to VOCs--i.e., persons identified by questionnaire as having "sick building syndrome." These findings are provocative because the available literature on individual compounds contained in the VOC mixture would not indicate any adverse effects at such low levels. The literature concerning the health effects of complex VOC mixtures is negligible.

The Mølhave study did contain some questionable areas in experimental concept and design, making it difficult for EPA to interpret the study and use it for quantitative risk assessment. This presents a significant problem to EPA since the study results are plausible in light of anecdotal reports related to sick building syndrome. We are sufficiently aware of Mølhave's work to believe that effects are quite conceivable, and there is no opposing information using the Mølhave approach in the published literature. Thus, there is reason to conduct a modified replicate experiment to independently confirm or

not confirm effects observed in humans. If EPA (or another organization) does not replicate Mølhave's work and publish the results in the peer-reviewed literature, there will forever be a question. Since the question is related to a human clinical study, the need is even more pressing.

Under the circumstances, we, along with an extramural group of experts, are currently designing a protocol which is a modified replication of the Mølhave study. Minor in scope, the study is expected to utilize approximately $100K of the FY-87 indoor air resources. At its conclusion, the results will determine the necessity for an expanded follow-up program.

A specific recommendation concerning our current research is that monitoring research aimed at measuring health effects of exposures or at source characterization and control should be pursued with a higher priority. The development of an Agency policy for indoor air quality has focussed our attention on integrating monitoring research with other programs. In the development of our research plan, we are closely examining the required balance between monitoring, health, and engineering.

The final major recommendation of the SAB is that the responsibility for the Agency's indoor air quality program be assigned to an individual of proven leadership and specific experience in this area. You further point out the need for a management structure which can both provide the leadership and be held accountable for the clear definition and implementation of research objectives.

We appreciate your concern for our management structure and talent within EPA. However, prior to the receipt of your report, I made management assignments for the indoor air program. These assignments, as discussed above, are those given to OAR for policy development and to ORD regarding a long-term research plan. Foremost is the goal of assuring public awareness of indoor air problems. OAR will design and subsequently implement the specifics of the program; ORD will coordinate all research on indoor air in support of this policy. The Assistant Administrator for ORD has appointed a Program Manager with full authority for coordinating all activities in ORD relating to indoor air. Responsibilities include: development of the ORD RNA, the design of the research program, negotiations on budget and funding and program implementation. In carrying out these tasks, the Program Manager has developed a management structure that includes both laboratory personnel who are directing research on indoor air and Headquarters personnel to ensure that the scientific questions of most importance to policy are being addressed. For this assignment, the Program Manager reports directly to the Deputy Assistant Administrator for ORD and is the principal ORD contact with other Agency offices concerning indoor air matters. As such, he serves as Co-chairman of the Indoor Air Quality Subcommittee of the ORD/OAR Air Research Committee.

The quality of our indoor air is of increasing interest to the general public as well as to the Agency. This timely review will contribute to the development and implementation of our research program for indoor air. Please accept my thanks and appreciation to you, as Chairman, and to the members of the Panel for your assistance.

Sincerely,

Lee M. Thomas

cc: Mr. A. James Barnes (A-101)
Dr. Terry Yosie (A-101)
Dr. Vaun Newill (RD-672)
Dr. Peter Preuss (RD-639)
Mr. Craig Potter (ANR-443)
Dr. Lester Grant (MD-52)

APPENDIX C

RESOURCE HISTORY
INDOOR AIR AND RADON

INDOOR AIR:

| | FY 1984 Total $(K) | FY 1985 Total $(K) | FY 1986 Total $(K) |
|---|---|---|---|
| MONITORING | 1465 | 1450 | 1410 |
| HEALTH EFFECTS | 125 | 100 | 250 |
| ENGINEERING | 462 | 550 | 578 |
| TOTAL | 2052 | 2100 | 2238 |

RADON:

| | FY 1984 Total $(K) | FY 1985 Total $(K) | FY 1986 Total $(K) |
|---|---|---|---|
| RADON EXPOSURE AND HEALTH RISK | | | |
| National assessment/state surveys | | 20 | 600 |
| Hazardous land evaluation | | | 200 |
| Measurement protocols | | | 140 |
| Health effects analysis | 200 | 293 | 20 |
| MITIGATION AND PREVENTION | | | |
| Mitigation demonstration program | 135 | 265 | 1500 |
| Develop radon chamber | | | 200 |
| House evaluation program | | | 410 |
| New houses | | | 100 |
| Study of fundamentals and devices | | | 50 |
| CAPABILITY DEVELOPMENT | | | |
| Training program | | | 340 |
| Quality assurance program | | | 250 |
| Support of State radon task force | | | 20 |
| PUBLIC INFORMATION | | | 30 |
| GENERAL SUPPORT | | | 90 |
| TOTAL | 335 | 578 | 3950 |

APPENDIX D

# CROSSWALK BETWEEN TITLE IV REQUIREMENTS AND EPA'S INDOOR RADON PROGRAM

| Title IV Requirements | EPA Program |
|---|---|
| Sec. 403(b)(1)<br><br>Research and development concerning the identification, characterization, and monitoring of the sources and levels of...radon, which includes research and development relating to<br>(A) the measurement of...[radon] concentrations and its strengths and sources<br>(B) high-risk building types<br>(C) instruments for...[radon] data collection | .Conduct a national assessment<br>.Provide technical assistance to State survey efforts<br>.Develop measurement protocols |
| Sec. 403(b)(2)<br><br>Research relating to the effects of ...radon on human health | .Conduct epidemiological studies to determine the link between lung cancer and radon exposure in houses |
| Sec. 403(b)(3)<br><br>Research and development relating to control technologies or other mitigation measures to prevent or abate... [radon] (including the development, evaluation, and testing of individual and generic control devices and systems) | .Develop and demonstrate cost-effective mitigation methods to reduce radon levels in houses<br>.Apply and evaluate mitigation methods |
| Sec. 403(b)(4)<br><br>Demonstration of methods for reducing or eliminating...radon, including sealing, venting, and other methods that the Administrator determines to be effective | .Study fundamentals and devices<br>.Issue technical guidance |

| | |
|---|---|
| Sec. 403(b)(5)<br><br>Research, to be carried out in conjunction with the Secretary of Housing and Urban Development, for the purpose of developing (A) methods for assessing the potential for radon contamination of new construction, including (but not limited to) consideration of the moisture content of soil, porosity of soil, and radon content of soil<br>(B) Design measures to avoid...[radon] | .Develop models to predict the potentia for structures built on certain land type to have elevated in- door radon concentr tions<br>.Develop and demon- strate techniques t prevent radon entry in new construction<br>.Develop model building codes<br>.Conduct cooperative radon prevention pr jects with HUD |
| Sec. 403(b)(6)<br><br>The dissemination of information to assure the public availability of the findings of the activities under this section | .Provide technical assistance to the States<br>.Conduct State training programs<br>.Implement a qualit assurance program radon measurement<br>.Establish a Federa clearinghouse for radon information<br>.Implement an effec tive public infor- mation program |

APPENDIX E

# OFFICE OF HEALTH AND ENVIRONMENTAL RESEARCH

# RADON RESEARCH PROGRAM PLAN

FEBRUARY 1987

The Office of Health and Environmental Research has developed this following plan to address its radon research needs and goals. This plan broadly defines the four goals which will provide the overall basis for the OHER current and future radon related activities. More detailed information can be obtained from the individual program areas.

the European Communities. In the near term, the expanded OHER radon program will provide information needed by state and local health departments, the building industry and the public. In the longer term, computer based analytical risk assessment capabilities using the database generated by this research program will be developed for the private sector, and state and local governments use.

Program Rationale

Public concern about indoor radon exposure is focussed on two questions:

- what health risk is associated with the exposures incurred in homes?
- if this risk is unacceptably high, what can be done to reduce it in a cost-effective manner?

There is also a third question, one that is currently less visible but of comparable importance:

- what can be done to avoid undue risks in future housing?

A closely related question of special concern to the Department of Energy, and to OHER in particular, is the following:

- what is the public health risk associated with possible future trends in radon exposures related to the application of advanced energy conservation technology in new housing?

To address these questions properly, a comprehensive research program is needed which includes many disciplines, e.g., health physics, fundamental radiation physics, chemistry, and biology, geology, soil science, aerosol physics, atmospheric physics and chemistry, epidemiology, structural engineering, and risk analysis. The magnitude of the effort required is suggested by the effort required to understand the analogous phenomena outdoors. It is likely that the risk associated with environmental radon exposure will not be adequately defined until models of lung cancer induction

## DOE/ER Plan for Radon Research Program

### Programmatic Goal

The goal of the program is to develop the quantitative data and principles that will allow accurate assessment of radon exposure and associated lung cancer risk under environmental conditions.

### Administrative Rationale and Coordination

The Office of Health and Environmental Research (OHER) has been a major sponsor of radon-related research for several decades. Under its auspices, considerable information has been generated from laboratory animal studies, studies of radon transport and diffusion into and within structures, and basic but related studies of internally deposited alpha emitters. In addition, OHER has augmented earlier Public Health Service studies on uranium miners with recent research on miners in New Mexico where exposure data are more accurate. Nevertheless, our knowledge is still neither general enough to yield predictive principles, nor quantitative enough to allow the accurate risk analysis on which rational policy decisions must rest.

Because of increasing societal concerns over radon health effects, OHER is planning a substantial expansion of its radon research program beginning in FY 1987. The program will be highly integrated: the OHER subprograms, carried out at geographically separated sites will be coordinated at Headquarters with one another and with related programs sponsored by the Office of Conservation and Renewable Energy (CE). The DOE program as a whole will be coordinated with programs of other agencies principally through the Federal Committee on Indoor Air Quality, whose radon work group is co-chaired by DOE and EPA, and with programs of other nations through the Commission of

Recent research results provide a useful framework for the design of such a program. Radon in the soil gas around the foundation has been identified as the dominant source of indoor radon in most structures, at least in the United States. Moreover, the flow of this soil gas across the building envelope appears to be mostly driven by pressure differentials across the foundation produced by thermal gradients and wind effects. An important goal of the proposed research program is the development of a detailed model of radon availability in the soil and transport into structures. Such a model could then be applied to the evaluation of mitigation techniques that focus on the reduction of the entry rate into structures, and would provide a reasonable basis for estimating the probability that high indoor radon levels would be found in particularly areas. A better understanding of the complex relationship between pressure differentials and ventilation rate would also be relevant to determining the radon risk from energy conservation.

A second research goal is to improve our capability for determining radon exposure and dose to the critical cells of the respiratory tract. New and improved measurement methodologies are currently being developed and evaluated, and this effort along with appropriate quality assurance programs should be maintained. Environmental influences on radon decay product properties, particularly concentrations, charge, and particle size, need to be better understood. Models of these phenomena can be applied to the evaluation of air-cleaning mitigation techniques and allow the inference of long-term exposure from short-term measurements. Finally, a much better understanding of particle deposition patterns and removal mechanisms and particle/critical cell geometry in the respiratory tract is needed so that the radiation doses to the target cells can be quantitatively estimated under various conditions of

exposure. This capability is especially important in the interpretation of data from controlled animal experiments in terms of human health effects.

A third goal of this program is to conduct appropriate epidemiological studies to quantify any relation between lung cancer incidence and environmental radon exposure. Such studies are unlikely to define dose-response relationships over the entire range of human exposures, but may provide reasonable estimates of risk at high exposure levels and suggest possible relationships between radon exposure and smoking in the induction of lung cancer.

The fourth and last goal is probably the most important one in the long run, namely, the development of a fundamental understanding of the role of radon in the induction of lung cancer. A detailed model of the process of lung carcinogenesis, even if highly phenomenological, would be extremely valuable in providing a firm basis for inferring the dose-response curve and determining the interaction between radon and smoking in lung cancer induction. Because of its immediate and practical importance, this goal deserves the full attention of the scientific community.

In the remainder of this document, each of the above goals will be discussed in detail.

## Program Description

### Goal #1: Model Development for Radon Availability and Transport

A detailed model is needed that relates radon concentrations indoors to the key factors that influence radon availability in the ground and the efficiency of soil gas transport through the soil and across the building envelope. Such a model can be used to evaluate the potential for high exposures in existing and future structures and to interpret field studies of the effectiveness of source-control mitigation techniques.

Recent research has identified many of the relevant factors and processes, and it may be said that we have a qualitative understanding of what is going on. Radium content of the soil, soil porosity, grain size, permeability, water content, pressure differentials, and diffusion all play a role. Details of building construction design are always important, a fact which places a fundamental limitation on the applicability of any model to individual structures. A more realistic goal for a model is the identification of areas where high indoor radon exposures are more likely to be found.

Among the key elements of a research program directed at this model development are the following:

(1) Laboratory and field investigations of radon availability in reasonably homogeneous geological formations and media so that quantitative relationships may be found between soil gas radon and the key physical variables, e.g., soil radium, emanation fraction, porosity, water, etc.

(2) Studies of radon transport in the ground under natural conditions in the absence of structures, e.g., the effects of soil porosity, permeability, and water content, and barometric pressure variations on diffusive and convective flow through homogenous and fractured media and across the air-ground interface.

(3) "Research-house" investigations involving detailed correlations of radon entry rates with measurements of relevant physical variables, e.g., soil gas radon pressure differential across the foundation, indoor and outdoor temperatures, outdoor wind speed and direction, soil moisture, ventilation rate, etc.

(4) Investigation of the applicability of existing geological and radiometric data, e.g., uranium geology, soil maps, airborne gamma surveys, regional radon surveys, to the development and validation of models of radon availability and transport.

In the conduct of this work, we will continue to coordinate our efforts with DOE/CE, EPA, USGS and the CEC program, all of whom are conducting related research.

Goal #2: Accurate Determination of Radon Exposure and Dose to the Critical Cells of the Respiratory Tract

The doses to the critical cells are strongly dependent on the deposition pattern of the inhaled radioactive particulates, which in turn depends on particle size and charge as well as many factors associated with the individual breathing pattern and respiratory tract morphology. The inference of long-term doses to these cells requires a full understanding of how environmental factors affect not only the concentrations of radon decay products in the ambient air but also the rate of neutralization of the initial positive ions of polonium-218, their rate of attachment to atmospheric particulates, and the rate of particle growth. A model of these processes that takes into account realistic air circulation patterns, ion, molecular cluster, and particle mobilities, chemical reactions, and deposition on surfaces is needed to interpret the limited available data on radioactive particle concentrations and size distributions and their changes with time. This model would find an important application in the assessment of the effectiveness of various air cleaning techniques for dose reduction.

New and improved methods for radon, radon decay product, and airborne particulate measurement are continually being developed in the DOE research

program and elsewhere. The DOE Environmental Measurements Laboratory (EML) has become the de facto national primary reference laboratory for environmental radon measurement, and has been actively involved in the evaluation of various measurement techniques and in the conduct of research laboratory intercomparisons. It is working closely with EPA and the states in the development of a national quality assurance program. These efforts to develop and test measurement methodologies will be maintained, as a means to assure that state-of-the-art technology is available to the private sector and the general public for the assessment of radon exposures.

The contribution of thoron decay products to total radon exposure and the consequent dose to the lungs needs to be better defined. The limited data on thoron now available indicate that this contribution can be significant in some situations. Moreover, the presence of thoron decay products can sometimes cause important errors in some types of radon measurements. Thoron itself may be of interest since, because of its short lifetime, it might be used as an indicator of the rapidity of transport of soil gas into a structure. Thus, attention should be paid to thoron in future research studies, where possible.

Methods for inferring long-term exposure to radon decay products from biological indicators need to be pursued further. One approach deserving further investigation is the use of lead-210 in the skeleton as such an indicator. Measurements of lead-210 accumulations in former mine and mill workers with substantial past exposures while they are still alive is likely to be important in testing the utility of this approach. In addition, highly sensitive laser analysis techniques have been developed for obtaining data on human exposure to uranium. These could be applied to bioassay measurements of appropriate radionuclides to infer recent exposures to radon decay products.

Although exposure in units of working level month (WLM) has been found to be a reasonably adequate surrogate for dose in epidemiological studies, a detailed understanding of the lung cancer risk from radon exposure (and the translation of the results of animal studies to human risk) requires a quantitative assessment of doses to the critical cells of the respiratory tract. Improved models of the lung are needed that take account of biological variability. The processes of particle deposition, transport, and removal must be thoroughly investigated, and uncertainties in the identity and location of the target cells resolved. Research that addresses these problems will have a high priority in an expanded ER program. It should also be kept in mind that it is unlikely that absorbed dose in the region of the critical cells is the relevant physical quantity in terms of risk. However, once the source-target geometry in the lung is adequately defined, microdosimetry, fundamental radiation physics and chemistry can be applied to the development of models of lung cancer induction (see Goal #4).

Goal #3: Assessment of Health Risk by Appropriate Epidemiological Studies

Current estimates of lung cancer risk due to exposure to radon and its progeny are derived from epidemiological studies of uranium miners in Colorado, Czechoslovakia, Sweden, and Canada. Ongoing OHER research is limited to case control studies of uranium miners in New Mexico, where dosimetric, medical, and lifestyle are superior to previous miner studies, and a recently initiated study of female lung cancer cases in Pennsylvania. These studies will provide more reliable data on lung cancer risk from exposure to radon in the mine environment.

While estimates of risk from domestic radon exposure may be extrapolated from the miner studies, they are inherently inaccurate for several reasons. The studies were conducted on men of a limited age range in an occupational

tions have a high percentage of smokers, non-malignant respiratory disease is highly prevalent among miners, and miners perform heavy manual labor. In the dusty mine environment, a high percentage of radon daughters are "attached" to particles. Since the attached fraction is lower in other environmental exposures, it has been suggested that the latter may result in dramatically increased delivered dose from a particular exposure level. Also, information on radon doses and on potentially confounding factors such as cigarette smoking is incomplete, and its validity somewhat questionable. Because the miner population is atypical, additional carefully planned epidemiological studies will be carried out to provide information on confounding factors, particularly smoking, and to provide information that will be applicable to residential communities.

Goal #4: Quantitative Model of Lung Cancer Induction Due to Radon Exposure

A major emphasis of the OHER radiation research program has been the investigation of the basic physical, chemical, and biological mechanisms of cancer induction following radiation exposure. An understanding of these mechanisms is required for the determination of dose-response relationships over the range of exposures normally encountered in the environment and in the workplace.

This general statement certainly applies to possible environmental radon exposures, which range over a factor of $10^4$. To some extent, the current radon risk estimates derived from the exposure of miners have to be extrapolated to higher exposures to cover the full range. Thus, there is a compelling need to target some of the existing effort on fundamental radiation physics, chemistry and biology within the OHER program on the particular endpoint of lung cancer. Different models of cancer induction may be needed

for the various cancers, and it is appropriate to concentrate on those few where the effect of radiation exposure is clearly important. An increased overall effort will be instituted to develop a fundamental understanding of the mechanisms of lung cancer induction and the respective roles of radon and smoking in this process. This effort will include the search for markers and oncogenes as well as modern cytogenetic studies. To determine cells at risk for tumor development, kinetic studies of tissue repair processes leading to metaplasia and neoplasia will be used, as will electron microscopy and chemical markers. The expression of oncogenes in the proliferating tissues will help characterize the progression of cellular events leading to neoplasia, and identify repair enzymes that may modify the disease process. Connection of these phenomena to the initial physico-chemical changes at the cellular and subcellular level due to the action of the incident alpha particles will be an essential feature of the ultimate model.

Experimental animal studies will be an important element of the expanded CHER program. Direct estimates of human risk may be derivable if the physical and biological differences between species can be properly accounted for. Possible interactions between radon and smoking in lung cancer induction can be investigated by varying the sequence of exposure to the two pollutants. Some existing evidence appears to imply that radon decay products primarly initiate the carcinogenetic process while smoking promotes the cancer growth. This is a very significant distinction that may strongly affect radon risk estimates. Finally, animal studies are necessary to understand particle deposition, transport, and clearance processes in the respiratory tract (see Goal #2).