United States General Accounting Office

GAO

Report to the Pennsylvania Congressional Delegation
House of Representatives

June 1986

AIR POLLUTION

Hazards of Indoor Radon Could Pose a National Health Problem

GAO/RCED-86-170

035920

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-223233

June 30, 1986

Members, Pennsylvania
Congressional Delegation
House of Representatives

As requested in your September 18, 1985, letter and subsequent discussions with your Steering Committee, this report provides information on the public's exposure to and the health effects of radon; cost and alternatives for reducing indoor radon levels; and federal efforts and statutory authorities and responsibilities to address indoor radon problems.

Overall, we found that various federal agencies are involved with the radon issue but that there is no one agency formally responsible for radon. Furthermore, the report states that although the Environmental Protection Agency (EPA) has assumed the federal leadership role for radon, its authorities to regulate radon and to provide financial assistance to alleviate radon hazards are unclear. The report concludes that radon is a growing national concern and that the Congress may wish to designate one agency responsible for federal radon efforts as well as clarify the radon activities the Congress desires the federal government to pursue.

In accordance with the Steering Committee's wishes, this report will be distributed immediately to the Administrator, EPA, and other interested parties, and to others requesting copies of the report.

J. Dexter Peach
Director

Executive Summary

Purpose

In late 1984, an eastern Pennsylvania nuclear power plant worker triggered radiation detectors in the plant. Investigation showed that he was radioactively contaminated, not by any source at the plant, but by high radon levels in his own home. The incident brought national attention to the issue of naturally-occurring indoor radon contamination.

At the request of the Pennsylvania Congressional Delegation, GAO developed information on

- the health effects of indoor radon and the extent of the public's exposure,
- alternatives and costs for reducing indoor radon levels,
- federal efforts to address indoor radon problems, and
- federal statutory authority and responsibility for addressing indoor radon issues.

Background

Radon is a colorless, odorless gas formed by the decay of radium and uranium. Radon produces radioactive products that can be inhaled into the lungs and can eventually cause lung cancer. Outdoors, radon poses no significant health risks because it is widely dispersed. Indoors, however, radon tends to concentrate because air flows less freely and can increase to hazardous levels.

A major source of indoor radon is the soil and rocks beneath and around a building. Radon seeps easily into homes through cracks and openings in foundation walls and floors, and more slowly through concrete walls and floors. Other potential radon sources include water from underground wells and building materials, e.g., brick and concrete. (See ch. 1.)

Results in Brief

Exposure to radon increases the risks of lung cancer. According to the Environmental Protection Agency (EPA), risks exist even at low exposure levels. In fact, EPA states that there is no safe level of radon exposure. Existing data, though not perfect, indicate that radon problems exist in most states. EPA plans a survey to determine national radon levels, but final results are over 3 years away.

Techniques for reducing radon vary in cost and success. In an 18-home demonstration project, EPA found that a home's site and structural conditions dictate the success of radon reduction techniques. EPA and others agree that information is inadequate for predicting whether or how much a particular technique will reduce indoor radon levels, or how much it will cost to lower radon levels.

No overall federal strategy exists to address the indoor radon issue. However, various federal agencies are involved in radon-related efforts. For example, EPA conducts research and provides technical assistance, and the Department of Energy (DOE) conducts research. Federal efforts are underway to coordinate federal radon research and policy, but it is too early to assess their success.

Various statutory authorities allow EPA and DOE to conduct radon research and provide technical assistance to states and homeowners. However, no clear statutory authority or responsibility exists for federally regulating radon or for providing financial assistance to alleviate indoor radon hazards.

Principal Findings

Radon Health Effects and Exposure

Studies of uranium, iron, and other underground miners in the U.S. and other countries show increased lung cancers among miners exposed to high radon levels in the work environment. Long-term studies of other populations affected by radon are limited. However, EPA and other scientists, such as those from the Centers for Disease Control, agree that exposure to radon increases the risk of lung cancer. Risks can further be complicated by other factors. For example, a person who sleeps in the basement is at more risk than one who sleeps on a second floor, and cigarette smokers face higher risks than nonsmokers.

Although radon increases the risks of lung cancer, little is known about the number of people exposed to radon and the various levels of radon exposure. EPA plans a national survey to determine the extent of radon exposure, but final results are not expected until late 1989 In the meantime, 30 percent of about 40,000 indoor radon measurements compiled by a private firm were above the level at which EPA recommends that action be taken to reduce indoor radon levels, indicating that indoor radon contamination is a national problem. (See ch. 2.)

Radon Reduction Techniques

EPA, as part of a planned 150-home effort, has an 18-home demonstration project to study the success of three techniques designed to reduce radon levels by drawing, or ventilating, radon gas away from a home before it can enter. In some homes, one technique reduced radon levels, while in others a different technique or more than one technique was necessary. Costs per home ranged from $4,300 to $15,700. Others involved in radon reduction work agree that no one can predict how much a particular technique will reduce indoor radon levels. As a result, it is not possible to accurately estimate how much radon reduction could cost individual homeowners (See ch. 3.)

Strategies for Addressing Radon

Although no overall federal indoor radon strategy exists, several federal agencies are involved in the issue. EPA conducts research and provides technical assistance to states and affected homeowners, and DOE conducts research The two agencies plan to spend $10.8 million during fiscal years 1985 and 1986 on radon-related research. Other federal agencies are involved to a lesser extent

In late 1985, EPA drafted a national strategy for addressing radon issues. The strategy proposes a federal role which consists primarily of (1) conducting research to determine radon gas exposure and health effects, (2) developing methods to prevent and mitigate indoor radon exposure, and (3) providing technical assistance and policy guidance to states to help them deal with radon hazards. (See ch. 4.)

Coordination of Federal Radon Policies

The Committee on Interagency Radiation Research and Policy Coordination established a group in February 1985 to develop a federal consensus on radon issues The Interagency Committee on Indoor Air Quality's radon group issued a report in May 1985 identifying key components of a radon research strategy. These groups also exchange information on radon research. Despite these efforts, some inconsistencies in agency radon practices exist. For example, EPA recommends one level at which homeowners should take corrective actions to reduce radon levels, while DOE's Bonneville Power Administration recommends a slightly higher level

Statutory Authority for Addressing Radon

The Clean Air Act, which establishes EPA as the lead federal agency responsible for air pollution control, does not give EPA specific legislative responsibility to regulate indoor air pollutants, such as radon. Further, other federal laws that provide for clean-up of environmental hazards or assistance in the case of natural disasters do not expressly assign responsibility or require response to naturally-occurring indoor radon hazards. (See ch 5.)

Matters for Congressional Consideration

It is too early to provide an overall assessment of the effectiveness of federal groups established to coordinate radon activities. Given the increased interest in radon, the number of groups involved, and questions about federal responsibility for radon, the Congress may wish to designate, in the interest of prudent oversight and clear accountability, one agency responsible for federal radon efforts. Because EPA is currently the most active organization in the indoor radon area, is responsible for air pollution, and has developed a strategy for addressing indoor radon problems, it would be the logical agency to choose for such a responsibility. (See ch. 5.)

If the Congress decides to make a federal agency responsible for overseeing federal radon efforts, it may wish to stipulate what activities should be conducted, such as research, technical assistance, regulation, or others. (See ch. 5.)

Agency Comments

GAO did not obtain official agency comments on this report; however, GAO did discuss the report's contents with EPA and other agency officials and has included their comments where appropriate.

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Abbreviations

BPA	Bonneville Power Administration
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CED	Community and Economic Development Division
CIAQ	Interagency Committee on Indoor Air Quality
CIRRPC	Committee on Interagency Radiation Research and Policy Coordination
CRCPD	Conference of Radiation Control Program Directors, Inc.
DC	District of Columbia
DOE	Department of Energy
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GAO	General Accounting Office
HUD	Department of Housing and Urban Development
NCRP	National Council on Radiation Protection and Measurement
ORD	Office of Research and Development
ORP	Office of Radiation Programs
pCi/l	picoCuries per liter (of air)
TVA	Tennessee Valley Authority
WL	working level
WLM	working level month

Introduction

The threat posed by exposure to naturally-occurring radon in homes in the United States came to national attention by an incident in late 1984. A Pennsylvania nuclear power plant worker was found to be highly radioactive. His exposure was traced back to his home in Pennsylvania, which is located on a geological formation, called the Reading Prong, that extends through New Jersey, New York, and Pennsylvania. Radon concentrations in the worker's home were as high as 130 times the federal occupational exposure standard for underground uranium mines. Subsequent testing by the state of Pennsylvania found high levels of radon in other homes.

In response to this situation, the Environmental Protection Agency (EPA) and the Department of Energy (DOE) assisted the state of Pennsylvania by providing technical assistance on radon measurement techniques, mitigation methods, and health effects information. Concern about indoor radon contamination in Pennsylvania and other areas of the country prompted the Pennsylvania Congressional Delegation in September 1985 to ask us to investigate the problems associated with indoor radon exposures, as well as the federal government's role and activities in responding to this problem.

Radon—An Overview

Radon is a radioactive gas produced naturally in the ground by the decay of radium. Radium is a byproduct of uranium, an element commonly found in varying amounts in most soils and rocks. Radon is colorless and odorless, will not burn or glow, and is undetectable by human senses.

Radon Is a Health Concern

Radon is a health concern because of the increased risk of lung cancer associated with exposure to it. Concern about the health effects of radon emerged from studies of underground workers in uranium, iron, and other mines which showed that miners exposed to high radon levels over a long period of time experienced excess lung cancer.

Radon remains a gas briefly, after which it breaks down, or decays, into radioactive products[1] that tend to adhere to dust and other tiny particles floating in the air. When inhaled, these radioactive particles can damage lung tissue. Outdoors, radon usually poses no significant health risk

[1]Radon has a "half-life" of 3 8 days, i e , for a given amount of radon, one-half of the radiation would be gone in 3 8 days, half of the remaining radiation would disappear in another 3 8 days, and so on Radon radioactive products are known as radon progeny and are also called radon daughters

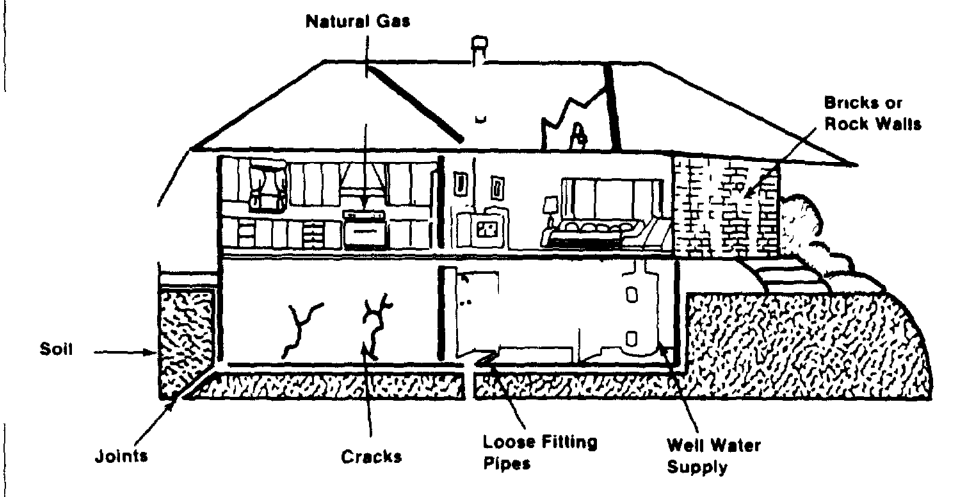
because it mixes with and is widely dispersed in the outside air. Indoors, however, the limited exchange between indoor and outdoor air (especially in energy efficient homes) prevents radon from escaping into the outdoors and can allow radon to increase to hazardous levels.

Sources of Indoor Radon

Radon can enter a home from several sources (see fig. 1.1). A major source of indoor radon is the soil and rocks surrounding a home. Because it is a gas, radon seeps easily into a home through cracks and openings in foundation walls and floors, and more slowly through concrete walls and floors. The amount of radon entering a home depends on a variety of factors, including the amount of radium in the soil surrounding or beneath a house, the soil's permeability, the type of house construction (e.g., basement versus crawl space), the condition of the home's foundation, and the air-tight quality of the home. Because of these factors, homes on the same block or beside each other can have different radon levels.

Radon can also enter a home in several other ways. For example, it may enter via water supplied by underground wells. As water comes in contact with the soil and rocks, it picks up radon. The churning of the water in washers, showers, and sinks releases the radon into the indoor air. Radon can also enter into a house from materials used in home construction, such as brick and concrete. Though considered a minor source, natural gas may also pick up radon in the ground and carry it indoors.

Figure 1.1: Sources and Entry Routes of Indoor Radon



Source Issue Backgrounder Energy Efficient New Homes & Indoor Air Pollutants, Bonneville Power Administration July 1985

Measuring Radon Levels

Radon gas concentrations are measured in terms of picoCuries per liter (pCi/l) of air and radon decay products are measured in working levels (WLs). Cumulative exposure to radon decay products is expressed in terms of working level months (WLMs). The WL unit of measure was developed to document the exposure of underground uranium miners to radon, hence its name. One WL is equal to approximately 200 pCi/l of radon; conversely, one pCi/l of radon is assumed to result in .005 WL of radon under normal conditions. One WLM is defined as exposure to one WL for 173 hours. As discussed in greater detail in chapter 2, EPA suggests that actions be initiated to reduce radon levels when such levels are .02 WL (4 pCi/l) or above. Throughout the report, the term radon is used synonymously with radon gas and radon decay products.

Because radon cannot be seen or smelled, specialized equipment is needed to detect its presence. There are several different devices which may be used to determine radon levels in homes. One commercially available device is a monitor about the size of a wrist watch that contains a piece of treated plastic. Radiation entering the monitor etches "tracks" on the plastic. The number of tracks appearing on the plastic indicates the level of radon. Another commercially-available device is a charcoal canister monitor, which absorbs dust and accompanying radon. Depending on the device used, the test period may range anywhere from 5 minutes to several months In general, the longer the test period, the more accurately the results will reflect a home's annual exposure to radon. Once a detector is exposed in a home, it must be analyzed by a qualified laboratory.

Methods for Reducing Indoor Radon

In general, the following methods can be used to reduce indoor radon levels.

Sealing Off Radon Entry Routes

To reduce radon gas entry into a home, homeowners can place barriers between the source material and the living space itself. This method entails several techniques, such as covering exposed soil inside a structure with concrete, sealing cracks in concrete floors and walls, adding traps to underfloor drains, and filling concrete block walls. Depending on the method used, costs can vary. The benefits derived from certain techniques, such as sealing cracks, may be negated over time as a home settles and new cracks appear. Sealing may be used in conjunction with other reduction methods.

Air Filtration

In this process, air is passed through high efficiency filters or electronic devices which collect dust and other airborne particles to which radon products attach themselves. Although the devices decrease the concentration of airborne particles and radon products attached to these particles, they may not decrease the concentration of smaller, unattached radon decay products, which can result in a higher radiation dose to the lungs.

Home Ventilation

This method involves increasing a home's air exchange rate—the rate at which incoming fresh air completely replaces existing air—either naturally (by opening windows or vents) or mechanically (through the use of fans). Home ventilation is perhaps the simplest method to use but, by its nature, may have limited applicability. That is, increasing the ventilation enough in some homes to reduce indoor radon levels would make the home drafty and would substantially increase utility bills.

Soil Ventilation

Soil ventilation prevents radon from entering the home by drawing the gas away before it can enter Soil ventilation techniques include inserting pipe into the stone aggregate under basement floors or into the hollow portion of concrete block walls to ventilate radon gas accumulating in these locations. Another technique involves attaching pipe to underground drain tile systems that surround some homes at the basement floor level, thereby drawing the radon gas in the soil away from the home. Fans are often attached to the system to improve ventilation. Soil ventilation normally requires installation and testing by competent, experienced professionals and can be both difficult and expensive in some homes. This method is the primary method EPA tested in its 18-home radon mitigation demonstration project discussed in chapter 3.

Air-To-Air Heat Exchanger

An air-to-air heat exchanger is a ventilation device which is designed to retain indoor heat as it exchanges indoor air and accompanying pollutants for fresh, outdoor air. Depending on the exchanger's design, heat from the indoor air is transferred via a series of pipes, a disc, or a plate to the air coming in from the outside. Most air-to-air heat exchangers are designed to ventilate an entire home, but some small models are designed to ventilate only a room or two. Like any central system, whole-house exchangers are best installed at the time the house is being built, when it is much easier to put in the necessary ductwork.

Objectives, Scope, and Methodology

By letter dated September 18, 1985, the Pennsylvania Congressional Delegation expressed concern about the growing problem of indoor radon contamination in Pennsylvania and other areas of the country and asked us to investigate the significance of the problem, the appropriateness of the federal government's response in addressing the problem, and the need for legislation. In subsequent meetings with the Delegation's Steering Committee staff, it was agreed that the objectives of our work would be to report on

- efforts to determine the extent of radon exposure and the knowledge that exists concerning radon's health effects,
- alternatives available to lower radon levels and the cost associated with the alternatives,
- strategies federal agencies are employing to address radon and the adequacy of coordinating these efforts, and
- whether federal agencies' authorities are adequate to establish a regulatory program and provide financial assistance to address radon.

We performed our work primarily at the Washington, D.C., headquarters offices of the Environmental Protection Agency and the Department of Energy, the two key federal agencies involved with radon; at EPA's research laboratory in Research Triangle Park, North Carolina; and at the Harrisburg, Pennsylvania, offices of the Pennsylvania Department of Environmental Resources and Department of Health. Overall, we contacted six federal departments and agencies and 19 state governments concerning efforts to identify and address indoor radon hazards. In addition, we contacted 13 other governmental and private groups regarding the indoor radon issue.

EPA's Office of Radiation Programs (ORP) is the agency's focal point for radon activities. We interviewed ORP officials for information on EPA's efforts to conduct a national survey of radon exposure, determine radon's health effects, and develop a national strategy for dealing with indoor radon hazards. We held similar interviews with officials of DOE's Office of Building and Community Systems, and Office of Health and Environmental Research; the Department of Housing and Urban Development's (HUD's) Office of Energy and Environment; the Bonneville Power Administration's (BPA's) Office of Conservation; and the Tennessee Valley Authority (TVA) concerning their efforts to identify and deal with radon. In addition, we interviewed the president of Terradex Corporation—a California-based radiation measurement firm—about the firm's radon measurement efforts and obtained data on nearly 40,000 radon measurements compiled by the firm from 1980 through April 23, 1986.

We contacted state officials in 19 states—California, Colorado, Florida, Illinois, Kentucky, Maine, Minnesota, New Jersey, New York, North Carolina, North Dakota, Oregon, Pennsylvania, Tennessee, Texas, Vermont, Virginia, Washington, and West Virginia—concerning efforts within each state to identify and deal with radon hazards and to obtain their views concerning the federal role in dealing with radon. We selected these states because of known or suspected radon problems, referrals by other states, or to provide geographical coverage. We used a structured telephone interview guide to obtain information from state officials.

To further obtain data on radon's health effects, we reviewed a May 1985 Centers for Disease Control report that evaluated 15 studies of lung cancer deaths among underground uranium, iron, and other miners exposed to radon. We also reviewed estimates prepared by EPA and others, such as the National Council on Radiation Protection and Measurement (NCRP), a congressionally-chartered, nonprofit group of radiation experts, on the risks of lung cancer from radon exposure. We discussed EPA's radon health risk estimates with the Deputy Director of EPA's Science Advisory Board. In addition, we reviewed a variety of scientific articles concerning radon and its health effects.

We reviewed files and interviewed Office of Research and Development (ORD) officials at EPA's Research Triangle Park laboratory for information on the status and results of EPA's 18-home radon demonstration project in Pennsylvania. We also discussed radon reduction issues with various public and private groups including (1) American ATCON and ARIX Sciences Incorporated, firms involved in designing and installing radon reduction technologies; (2) the Buffalo Design Group, a private contractor in the Reading Prong area involved in radon mitigation work; and (3) the Pennsylvania Association of Home Builders. We also contacted the director of the Office of Public Information and Legislative Affairs, Pennsylvania Housing Finance Agency, for information on the objectives and accomplishments of Pennsylvania's state loan program for financing radon reduction techniques in private homes.

To obtain information on federal strategies for addressing radon, we reviewed a draft of EPA's national radon strategy and discussed it with ORP officials. We also obtained information on (1) the objectives, cost, and status of ongoing radon research projects funded by EPA, DOE, and other federal agencies and (2) the federal radon research and policy activities of two federal radiation groups—the 16-member Interagency Committee on Indoor Air Quality (CIAQ) and the 18-member Committee on Interagency Radiation Research and Policy Coordination (CIRRPC). We interviewed the executive secretary of the Conference of Radiation Control Program Directors (CRCPD), a state radiation coordination group composed of representatives from the 50 states, for information on the group's radon efforts.

For information regarding federal statutory authorities to address radon hazards, we reviewed the Clean Air Act and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly referred to as "Superfund") concerning EPA's authoritities to (1) establish a federal regulatory program for indoor radon and (2) take corrective response actions to alleviate indoor radon hazards. The Clean Air Act represents EPA's basic authority for dealing with air pollution, and CERCLA represents EPA's only legislation directly involving disaster assistance and/or responses to emergency situations. We discussed these laws with EPA's Office of General Counsel. We also discussed the Federal Emergency Management Agency's (FEMA's) authorities under the Disaster Relief Act to provide financial assistance to mitigate indoor radon hazards with FEMA's Office of General Counsel.

Our work was performed from October 1985 through May 1986. As requested by the Pennsylvania Congressional Delegation Steering Committee, we did not request official agency comments on a draft of this report, but we did discuss its contents with EPA and officials of other agencies and have included their comments where appropriate. Except as noted above, our work was performed in accordance with generally accepted auditing standards.

Radon Health Effects and Exposure

Exposure to radon gas increases the risk of developing lung cancer. Health studies have established such risks among underground miners who worked in mines where high levels of radon were present. Similar studies documenting excess lung cancers in humans exposed to low levels of radon are not as numerous or conclusive; however, EPA and other scientific groups agree that increased risks of lung cancer exist at these lower levels. In fact, EPA takes the position that there is no safe level of radon exposure.

Although radon increases the risks of lung cancer, the number of people exposed to radon and the various levels of exposure are not known. Without such information, it is difficult to make reliable estimates about the number of lung cancers expected from indoor radon exposure. EPA plans a national survey to determine the extent of indoor radon exposure nationwide, but final results are not expected for at least 3 years. Although the magnitude of the indoor radon problem is not yet known, existing radon testing data show some high radon levels in nearly every state, indicating that indoor radon contamination may be a national problem.

Radon Increases Risk of Lung Cancer

Evidence that exposure to radon increases the risk of developing lung cancer comes primarily from studies of workers exposed to radon in underground uranium, iron, and other mines. At least 15 studies of radon exposure, conducted in the United States, Canada, and other countries, have reported excess lung cancers among miners. A study of 4,146 American uranium miners exposed to radon, for example, showed 173 lung cancer deaths above the expected norm for the group even after adjusting for smoking and other contributing factors. Mining studies have associated excess lung cancers with cumulative lifetime exposure to radon above 80 WLM, but one study, involving uranium miners in Ontario, Canada, reported excess lung cancers associated with cumulative lifetime exposures as low as 40 WLM.

According to EPA and other scientific groups, scientific evidence exists that supports the link between exposure to high levels of radon and excess lung cancers, but there are, as yet, few health studies that definitively link low-level radon exposure to lung cancer Nevertheless, these groups agree that radon poses a health risk, even at the low levels of exposure found in many residential structures. Evidence supporting this view is generally based on extrapolating the results of the mining studies down to the lower radon exposure levels.

In June 1986, EPA provided us with its latest estimates of excess lung cancer deaths that would result for every 1,000 people exposed to a particular level of radon over their lifetime. These estimates, which EPA plans to include in its pamphlet, "A Citizen's Guide to Radon" scheduled to be published in July or August 1986, are presented in table 2.1. Overall, they show that a risk exists of developing lung cancer at all levels of radon exposure. In fact, EPA notes in a draft of the guide that exposure to a low level of radon for a long period of time may present a greater risk than exposure to a high level for a short period of time. EPA also points out that lifestyles can affect the risks of lung cancer from radon. For instance, exposure to tobacco smoke in homes with radon may further increase the risks of lung cancer. Also, some studies indicate that children are more sensitive to radiation exposure and, therefore, face greater risks from radon. EPA also notes that radon levels tend to be greater in the lower levels of a home and, consequently, a person who sleeps in a basement bedroom is likely to face a greater risk than a person who sleeps in a second-floor bedroom.

Table 2.1: Estimates of Excess Lung Cancers From Radon Exposures

Radon exposure levels (WL)	Persons per 1,000 expected to die of lung cancer[a]
1 0	440 - 770
0 5	270 - 630
0.2	120 - 380
0 1	60 - 210
0.05	30 - 120
0.02	10 - 50
0 01	7 - 30
0 005	3 - 10
0.001	1 - 3

[a]Based on (1) lifetime exposure of approximately 70 years and (2) 75 percent occupancy in a dwelling with elevated radon levels

EPA Believes There Is No Safe Level of Radon Exposure

Although EPA recommends that corrective action be taken to reduce radon levels when such levels are .02 WL and above, EPA maintains that this does not mean that radon levels below .02 WL are acceptable. In a February 21, 1986, response to the Chairman, Subcommittee on Natural Resources, Agriculture Research and Environment, House Committee on Science and Technology, on a series of questions on radon, EPA took the position that there are no safe levels of radon exposure. EPA further stated that it considered economic as well as health factors in developing the .02 WL criterion.

In addition to estimating the risks of radon exposure, EPA's draft citizen's radon guide also provides information on when remedial action should be taken to alleviate indoor radon exposures. Overall, the guide recommends that .02 WL be used as a target for initiating corrective actions to reduce indoor radon levels. The guide also points out that the higher the radon concentration in a home, the faster the homeowner should act to reduce indoor exposure levels. The guide suggests that the guidelines in table 2.2 be used by homeowners in considering whether and how quickly to initiate corrective action to reduce radon levels.

Table 2.2: EPA Suggestions for Initiating Corrective Actions to Reduce Radon Levels

Exposure levels	Suggested actions
1 0 WL or higher	Take action within several weeks to reduce levels as far below 1 0 WL as possible If this is not possible, resident should consider temporarily relocating until levels can be reduced
1 WL to 1 0 WL	Take action within several months to reduce levels as far below 1 WL as possible
02 WL to 1 WL	Take action within a few years to reduce levels to about 02 WL or below
About 02 WL or below	Exposure in this range presents some risk of lung cancer but reductions of levels this low may be difficult and sometimes impossible

Immediate actions identified by EPA's citizen guide that can be taken to reduce exposure to radon include (1) avoiding smoking; (2) avoiding spending time in areas with high radon levels, such as basements; and (3) opening all windows and turning on fans so that outside air flows into and through the house. More permanent remedies identified by EPA to reduce radon levels include sealing holes in concrete walls and floors and installing fans to ventilate radon away from the homes The guide advises that homeowners, before undertaking the more permanent remedies, have follow-up monitoring done to confirm the levels of radon exposure and to identify those places where radon is most likely entering the home

Because EPA believes that there is no safe level of exposure to radon, humans face some degree of risk even if they live in a home with radon levels below EPA's radon action guideline of 02 WL. According to EPA's own estimates, as shown in table 2.1, 10 to 50 persons are likely to die of lung cancer out of 1,000 persons exposed to .02 WL over their lifetime. Because of this, EPA does not endorse .02 WL as a safe level.

Lack of Reliable Exposure Data Limits EPA's Ability to Estimate National Health Risks

While it is recognized that exposure to radon increases the risks of developing lung cancer, little is known about how many people are exposed to radon across the country and about the levels of radon exposure. A number of radon measurement efforts have been conducted nationwide, but these efforts have varied in terms of objectives, selection of homes, and measurement procedures. As a result, the studies do not provide a reliable basis for estimating the radon concentrations to which the U.S. population is exposed.

Without information on the number of people exposed to radon and the levels of exposure, estimates of the total number of lung cancer deaths due to indoor radon depend largely on assumptions about the distribution of radon levels in U.S. homes. Several scientific groups, for example, have estimated that from 5,000 to 20,000 lung cancer deaths occur annually from indoor radon exposure by assuming an average exposure level of .004 WL for all U.S. homes. (The range in the number of deaths results from the use of different risk estimates by the various groups.) EPA, in commenting on the 5,000 to 20,000 figure, noted that .004 WL is probably a low estimate of national radon exposure and that better data on the national distribution of radon levels will probably show an even larger number of estimated lung cancer deaths.

EPA's National Survey

Recognizing the need to establish data on radon exposure nationwide, EPA is planning a national survey that will determine (1) radon levels in residential structures across the country and (2) whether an association exists between geological conditions and radon levels in residential structures. The survey will measure indoor radon levels and develop construction characteristics and other information on an as yet undetermined number of residential structures across the country. Work on the survey design is expected to be completed by October 1986. EPA plans a pilot test in about 250 homes to be completed in March 1987 and expects to begin the actual survey in July 1987. EPA anticipates that data collection will take 21 months to complete, with an additional 6 months needed to analyze the data and report the results. Overall, EPA anticipates completing the survey and the data analysis by October 1989.

Other Federal/State Radon Testing Efforts

In addition to EPA's national survey, other federal and state efforts are directed at testing radon levels. The Bonneville Power Administration is providing free radon detectors to homeowners participating in BPA's home weatherization effort. BPA initiated the testing effort after recognizing that installing storm windows and other energy-saving measures under its weatherization program exposed the occupants to increased levels of radon and other indoor air pollutants. BPA's project manager for its radon monitoring program told us in March 1986 that detectors had been installed in 42,000 homes served by BPA.

Our discussions with state radiation and health officials in 19 states showed that state-sponsored radon testing efforts are underway or planned to better define state exposures in 16 of these states. For example, the director of the Florida Office of Radiation Control told us that the state of Florida plans to conduct a 5-year, statewide radon survey involving 6,600 homes. The state contains about 420,000 acres of phosphate lands. Phosphate, in its natural state, is laced with radon-producing uranium. Testing is expected to begin in July 1986.

The state of Pennsylvania is planning to expand its free radon testing program to areas beyond the Reading Prong. The Director, Bureau of Radiation Protection, Pennsylvania Department of Environmental Resources, told us in April 1986 that the state had sent letters to several thousand homeowners in the area around Easton, Pennsylvania, announcing free radon testing. This official told us that the state would also like to initiate radon testing in a suburban Philadelphia area, where the geology is similar to the Reading Prong, but that testing in and around the Reading Prong is consuming most available state resources. As of early March 1986, state-provided radon detectors were in 21,000 Reading Prong homes.

Other state-sponsored efforts include New York, where the state has provided 3,000 randomly selected homes statewide with 3 detectors each (9,000 detectors) to measure indoor radon levels. In April 1986, the director of the New York State Energy Research and Development Authority told us that about 2,300 detectors had been returned but that it would be July or August 1986 before any results from these detectors were published. In New Jersey, the state has approved a $3.2 million radon effort that includes monitoring 6,000 homes to determine radon exposure levels. In Virginia, the state began testing 800 homes statewide in March 1986 for radon levels. According to the director of the Virginia Bureau of Radiological Health, test results are expected to be available around August 1986.

Existing Exposure Data Indicate That Radon May Be a National Problem

Although the magnitude of the radon problem is not well defined, test data compiled by a private radon testing firm show high radon levels in nearly every state and indicates that radon may be a national problem. Testing programs in several states also indicate high radon measurements.

Terradex and State Data

Radon measurements compiled by Terradex Corporation, a major radon testing firm, currently represent the largest and most extensive data set on radon exposure levels across the country. From 1980 through April 23, 1986, Terradex compiled data on 39,536 indoor radon measurements for an estimated 20,000 homes in the 50 states and the District of Columbia (DC). Terradex's analysis of the data showed that (1) 47 states and DC had at least one home with radon levels above 4 pCi/l (equivalent to .02 WL, the level at which EPA recommends corrective action should be taken to reduce radon levels) and (2) 30 percent of all radon measurements across the country were above the 4 pCi/l level. No measurements above 4 pCi/l were reported in Hawaii, Oklahoma, and Mississippi. The firm's analysis of the data by region showed measurements over 4 pCi/l ranged from a high of 47 percent for the northeast region to a low of slightly over 4 percent for the northwest. Appendix II lists the median and average radon levels and the percent of radon measurements over 4 pCi/l as reported by Terradex.

In discussing the results of its analysis, Terradex noted that its data had several limiting features and could not be used to draw precise conclusions about U.S. exposure to radon. Terradex stated, for example, that the radon measurements were not the result of a statistically designed survey to define national exposure. Instead, many different Terradex clients performed the measurements for a variety of reasons. The firm noted that most states (44 and the District of Columbia) had less than 1,000 measurements each, which was inadequate to define a state population's exposure to radon. Despite its limitations, Terradex concluded that the data show that there are some homes with unacceptably high radon levels in nearly every state and that, in certain regions, a significant fraction of homes have unacceptably high radon values. According to the president of Terradex, the firm expects to have data on 50,000 radon measurements by the end of 1986.

States have also found high radon levels during their radon testing efforts. Our discussions with state radiation and health officials in 19 states showed that several had test data that showed homes with radon levels above EPA's .02 WL criterion. For example:

- In Florida, radon levels in about 200 of 1,000 homes (20 percent) tested by the state and Polk County were above .02 WL
- In New Jersey, state testing of 71 homes in Clinton, New Jersey, found that all 71 homes had radon levels above .02 WL; 36 of these homes (51 percent) had radon levels of 1 WL or above; and 5 homes had levels of 5 WL or above.
- In Chicago, Illinois, 20 percent of 144 homes tested by DOE contained radon levels above EPA's criterion.
- In New York, radon levels in at least 14 of 133 homes (11 percent) tested by DOE and two power companies exceeded EPA's criterion.
- In Pennsylvania, state testing of 2,690 Reading Prong homes found 1,193 (44 percent) with radon levels above .02 WL, with 20 homes having radon levels of 1 WL or above.

Conclusions

Studies of underground miners in this country and abroad, and other data, show that exposure to radon increases the risk of developing lung cancer. Furthermore, according to EPA, there is no safe level of radon exposure. EPA risk estimates show that exposure to radon levels even below the agency's suggested remedial action level can add to a person's chances of developing lung cancer

Although the adverse health effects associated with exposure to radon are well established, questions remain regarding the number of persons in the United States currently being exposed to radon and their levels of exposure. Estimates, based on limited data, show that radon exposures may cause from 5,000 to 20,000 lung cancer deaths annually. Improving the estimates of how many people may develop lung cancer from radon requires better data on (1) the number of people exposed to radon and (2) their levels of radon exposure. EPA is designing a national survey that will develop such information, but final results are at least 3 years away In the meantime, evidence from a variety of existing radon measurement efforts, although not perfect, shows that radon problems exist in most states and indicates that radon may be a national problem affecting most areas of the country.

Alternatives and Costs of Reducing Indoor Radon Levels

EPA has a project underway, eventually involving 150 homes, to test the effectiveness of radon reduction techniques in lowering indoor radon levels Initial results from its work in 18 homes in Pennsylvania, and the experiences of others involved with radon reduction work, show (1) that a home's structural and site conditions dictate the success of radon reduction techniques in reducing radon levels and (2) that no one can predict which techniques will work best under which conditions or how much radon levels will be reduced EPA's work has also shown that the cost of radon reduction varies from home to home and that, for some homeowners, the cost of reducing radon may be high

EPA's 18-Home Radon Reduction Demonstration Project Shows Mixed Results

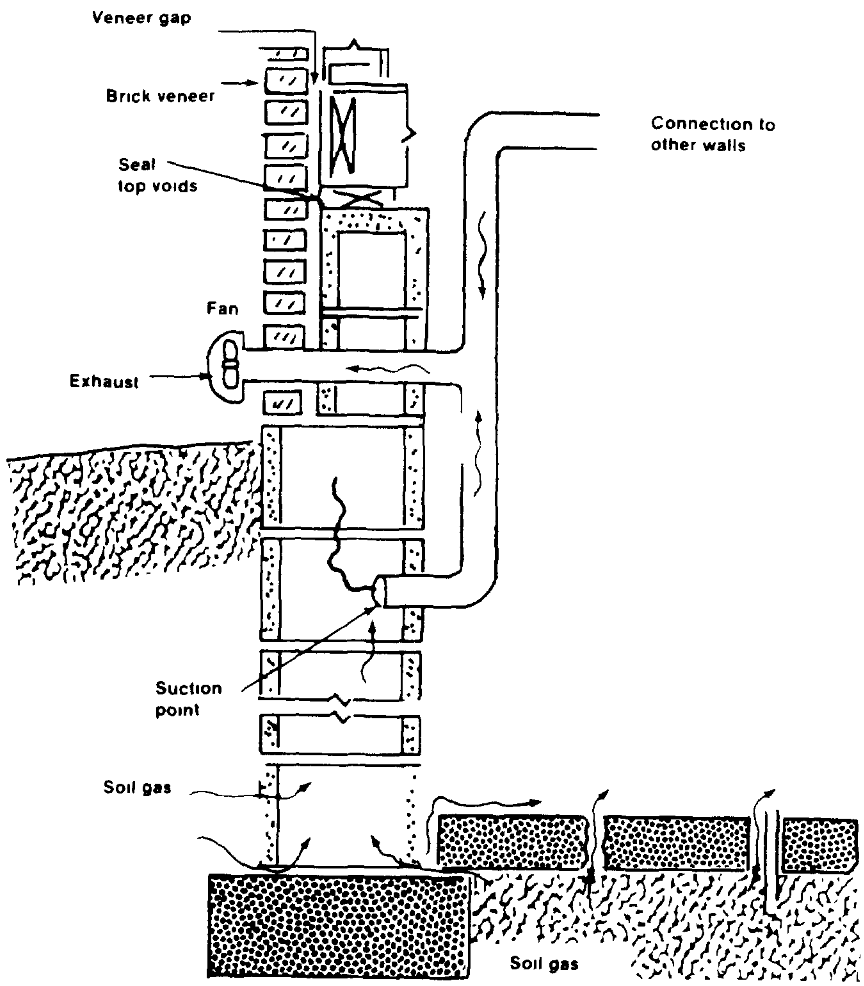
As part of its radon research, EPA is conducting a project to demonstrate low-cost techniques for reducing radon in existing structures and for incorporating radon-resistant techniques into new-home construction [1] The first phase involves an 18-home project in the Reading Prong area of Pennsylvania to demonstrate the effectiveness of three soil ventilation techniques in reducing indoor radon

According to EPA, initial results from its 18-home Reading Prong project show that the project has had mixed success in demonstrating soil ventilation as an effective and low-cost method of reducing indoor radon levels and that site and structural conditions play a major role in the success of reducing radon levels. EPA reduced radon levels in the 18 homes, but according to the EPA Office of Research and Development official serving as the Reading Prong project officer, none of the homes, as of March 31, 1986, had consistent radon levels below EPA's 02 WL criterion While total cost data were not available for all the work EPA performed on each home, cost data provided us by EPA showed that the amount EPA spent on radon reduction work ranged from a low of about $4,300 to a high of over $15,700

The 18 homes, selected from a universe of 150 homes, had radon levels of 0.1 WL or higher, and all had basements with concrete-block walls. The project involved initially installing one of the following three soil ventilation techniques in 17 homes ventilation of the network of openings within the concrete-block walls (wall ventilation) in 6 homes; ventilation of underground drainage systems surrounding the homes at basement floor level (drain tile ventilation) in 7 homes, and ventilation of stone aggregate beneath the basement floor (sub-slab ventilation) in 4

[1] EPA defines low cost as an installed cost to the homeowner of less than 2 percent of the market value of the house

Figure 3 1 Wall Ventilation System
(Concrete Block Wall)



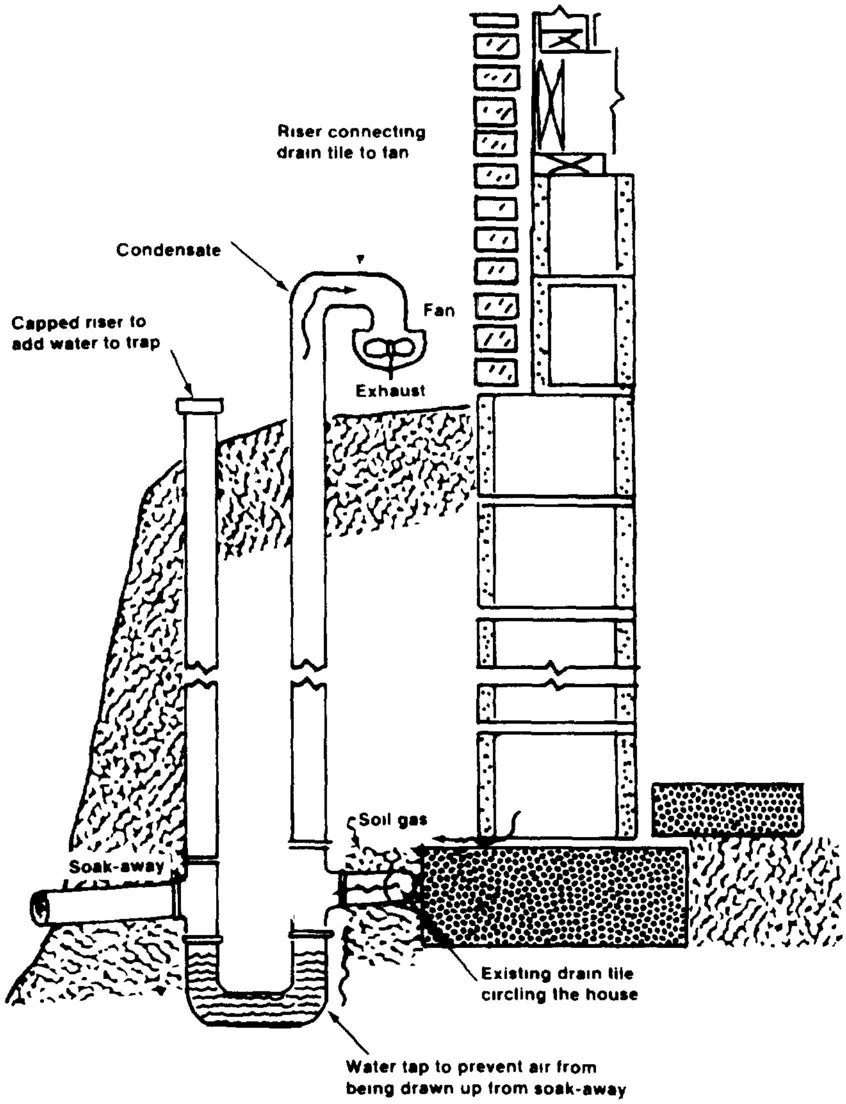
Source The EPA Program to Demonstrate Mitigation Measures for Indoor Radon Initial Results presented at International Specialty Conference on Indoor Radon Philadelphia Pa February 24-26 1986

homes Figures 3 1 through 3 3 illustrate these three techniques In the 18th home, EPA modified the home's forced air furnace system to bring in outdoor air

Results Fluctuate by Season

The degree of radon reduction in EPA's demonstration project homes varied by season According to EPA, radon measurements taken during June through August 1985—after installation of the mitigation techniques—showed that radon levels declined in 16 of the 18 homes by

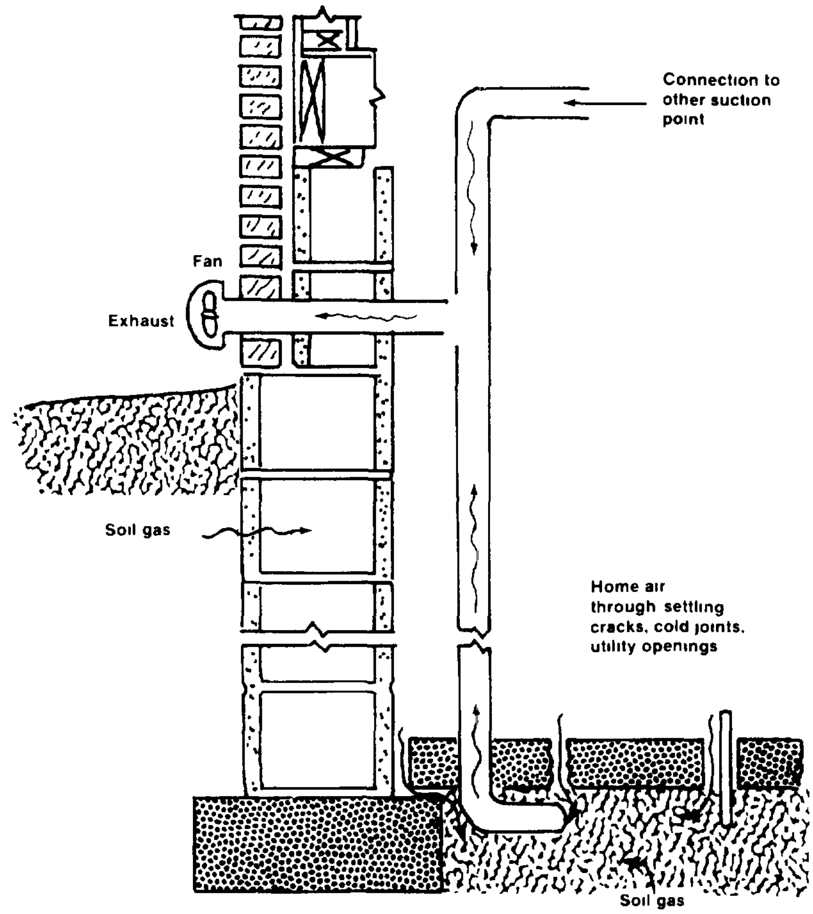
Figure 3.2 Drain Tile Ventilation System



Source The EPA Program to Demonstrate Mitigation Measures for Indoor Radon Initial Results presented at International Specialty Conference on Indoor Radon Philadelphia Pa February 24-26 1986

anywhere from 58 to 99 percent In the two remaining homes, radon levels were unchanged Winter measurements during the months of November 1985 through January 1986 showed that radon levels in at least 10 homes had increased above the summer levels and, in at least 3 of these homes, above pre-mitigation levels

Figure 3 3 Sub-Slab Ventilation System



Source The EPA Program to Demonstrate Mitigation Measures for Indoor Radon Initial Results, presented at International Specialty Conference on Indoor Radon Philadelphia Pa ,February 24-26 1986

Unique Site and Structural Conditions Affect Radon Reduction Results

EPA's work in the 18 homes showed that successfully mitigating radon depends primarily on identifying radon entry routes into a home and on a home's site and structural conditions The following examples demonstrate how site and structural conditions of a home can affect the results of radon reduction efforts

- In one of the homes where sub-slab ventilation was installed, no reduction occurred in the summer months because stone aggregate had not been placed beneath the basement floor. As a result, the system was unable to ventilate the entire area under the slab EPA subsequently installed a wall ventilation system and made other modifications, which included painting the porous concrete block basement walls. As of March 31, 1986, radon levels in this home had been reduced to 1 WL and below, according to EPA's Office of Research Development official serving as project officer.

- In another home with sub-slab ventilation, radon levels increased from a summer high of 23 WL to a winter high of 7 4 WL. EPA found that although the sub-slab system was ventilating the gas from beneath the slab, radon was drawn into the home up through the voids in the concrete block walls when the heating system was operating EPA subsequently installed a wall ventilation system and an air-to-air heat exchanger As of March 31, 1986, radon levels in this home were 05 WL and below According to the ORD Reading Prong project officer, EPA believes that well water coming into the home may be contributing anywhere from 02 to 03 WL of radon, and plans to treat the water to further reduce the radon levels
- In one home with wall ventilation, radon levels increased from a summer high of 06 WL to a winter high of 2 5 WL. Wall ventilation relies on suction to reduce radon, in this home, two factors significantly reduced the suction (1) the top row of concrete block in the basement wall was unsealed and (2) a void existed between the house and the brick-veneer wall surrounding the house EPA modified the system by installing larger ducts and a larger fan to draw more air. The ORD Reading Prong project officer told us that as of March 31, 1986, radon levels in this particular home had dropped to 05 WL and below EPA noted that, in general, one or more of the following conditions affected wall ventilation system performance inaccessible openings in the top row of the concrete block basement walls, exterior brick-veneer walls, or a fireplace built into the block wall

In summary, EPA performed additional mitigation work in 10 of the 18 homes in an attempt to reduce the radon levels to EPA's 02 WL criterion, and to better understand why a particular method did not work The EPA Reading Prong project officer told us that EPA plans further radon testing in 12 of the 18 homes during the 1986-87 winter months to further evaluate the success of its radon mitigation work

Mitigation Costs Vary From Home to Home

Data available as of April 1986 on EPA's 18 home project show that radon mitigation costs varied from home to home This information reflects the cost to initially install the techniques in all 18 homes and to perform additional mitigation work on 6 of the 18 homes

As shown in table 3 1, EPA's cost for initial radon mitigation work on the 18 homes, including the services of a radon mitigation consultant, ranged from a low of $4,300 for modifying the forced-air furnace system to a high of $10,239 for a combined sub-slab and wall ventilation system EPA estimates the cost to homeowners for comparable contractor-installed systems would range from a low of $300 for the furnace ventilation system to a high of $5,500 for the sub-slab/wall ventilation system The primary difference between the costs is that EPA's includes $4,150 per home to cover the cost of a radon mitigation consultant, the homeowner's cost does not include a charge for such services EPA based its homeowner cost estimates on the direct labor and materials costs it incurred for each home, plus a 70 percent increase to cover the cost of construction crew supervision and follow-up monitoring after mitigation work

Table 3.1. Cost of Initial Radon Mitigation Work for the 18 Homes by Ventilation Technique

Technique	Number of homes	Range of EPA costs	Range of EPA-estimated costs to homeowners
Sub-slab ventilation	4	$5 049 - $10,239	$1,500 - $3,300
Wall ventilation	6	$5,511 - $ 7,404	$2 300 - $5,500
Drain tile ventilation	7	$4,557 $ 4,905	$ 700 - $1,300
Furnace ventilation	1	$4,300	$300

Two factors influence the reliability and applicability of EPA's cost data to homeowners' actual radon mitigation costs First, while EPA's data represent the actual or estimated cost associated with installing a particular radon mitigation technique, they do not represent the cost that a homeowner may have to incur to effectively reduce indoor radon levels As noted previously, EPA performed additional radon mitigation work in 10 of the 18 homes, which increased EPA's costs The extra work on 6 of the 10 homes cost an additional $24,710 in direct labor and material costs and ranged anywhere from about $1,900 to $9,200 per home, according to EPA's project officer In total, EPA spent over $15,700 on one home and nearly $14,800 on another home

Second, EPA's costs include a charge to cover the services provided by a radon mitigation consultant, an item EPA did not include in estimating homeowners' mitigation costs EPA assumed that homeowners would not require a consultant's services and that a construction contractor could accomplish the necessary construction crew supervision and testing after mitigation However, EPA's experience with the 18 homes in identifying all radon entry routes and installing radon mitigation techniques indicates that (1) homeowners will require some type of consultative services in deciding how radon is entering a home and determining which techniques offer the best potential for radon reduction and (2) EPA's cost estimates for homeowners, as presented in table 3 1, may not realistically reflect the cost a homeowner may expect to incur in reducing indoor radon levels

EPA's Other Radon Mitigation Work

In addition to its 18-home project, EPA has other radon mitigation research underway or planned to demonstrate methods for mitigating radon and to provide homeowners and others with information on reducing indoor radon levels

As of April 1986, mitigation work was underway at 12 additional homes in the Reading Prong area, including 4 homes with poured concrete basement walls EPA expects to complete the mitigation work on these 12 homes in July or August 1986 and will then start mitigation work on 24 more homes in eastern Pennsylvania In the fall of 1986, EPA plans to perform radon mitigation work in about 100 homes in four regions across the country, with 30 of these being newly constructed Other EPA radon mitigation efforts include (1) a 15-home project by the University of California's Lawrence Berkeley Laboratory to better understand how radon enters a home, and the factors that affect radon entry, and (2) a 10-home project in the Clinton, New Jersey, area to reduce high levels of radon discovered by state testing

In addition to its mitigation projects, EPA has developed a manual and a brochure to provide homeowners and others with information on radon mitigation techniques EPA expects the manual and brochure to be published and available for general distribution in July or August 1986.

Other Views on Radon Reduction Techniques and Costs

In addition to EPA's research, experiences of others involved in radon mitigation work show that site and structural conditions dictate the success of techniques in reducing indoor radon levels.

The University of California's Lawrence Berkeley Laboratory, with funding from BPA, tested basement pressurization[2] and sub-slab ventilation techniques in nine homes. The Lawrence Berkeley project manager told us that while each method showed promise of being effective in reducing radon, the degree of reduction varied from home to home because of the characteristics of each home. He told us that before a radon reduction method is actually applied, radon testing should be conducted and an evaluation made of how radon is entering the home.

We also discussed the success of radon mitigation techniques with the American ATCON consultant working on EPA's 18-home radon mitigation project and with the president of ARIX Sciences, Inc.—a radon mitigation firm which has done mitigation work in Colorado, Montana, New Jersey, and Pennsylvania. While they agreed that a variety of radon mitigation techniques exist, they acknowledged that site and structural conditions of a home make it difficult to predict how successful a technique will be in reducing indoor radon levels. The American ATCON consultant, for example, told us that he had installed a sub-slab ventilation system in one Reading Prong home. He told us that while this type of ventilation technique is conceptually sound, it did not lower radon levels in this instance. He further stated that the only way to determine why the system did not work would be to "dissect" the home.

In addition to the cost data from EPA's 18-home project, we obtained cost estimates from the president of ARIX Sciences, Inc.; the president of the Buffalo Design Group, a mitigation contractor in the Reading Prong area; and the product manager for Airxchange, an air-to-air heat exchanger manufacturer. The president of ARIX told us that, in his opinion, contractors could "radon proof" new homes—e.g., sealing the outside basement area with a radon-resistant vinyl or installing wall and sub-slab ventilation—at a cost of 6 to 10 percent of the total construction cost. He added that correcting radon problems in some existing homes would be more expensive and could possibly cost the homeowner as much as the home's existing value.

[2] A radon reduction technique in which air flow into a basement is increased in order to raise the basement's air pressure above that of soil surrounding and beneath the home

The president of the Buffalo Design Group provided cost estimates relating to three radon mitigation techniques—general sealing, sub-slab ventilation, and air-to-air heat exchangers. He stated that the cost to seal a basement with a radon-proofing material would be about $2 to $2.50 per square foot, or about $2,000 per home. Installing a sub-slab ventilation system would cost about $600 if the home has a gravel layer under the floor, and installing air-to-air heat exchangers would cost between $1,200 and $2,000. The Airxchange product manager told us that his firm's air-to-air heat exchanger system could be installed for between $800 and $1,200.

Conclusions

A variety of methods exist for reducing indoor radon levels. However, no method has demonstrated its reliability to consistently reduce radon levels, and no one can predict which method will work best under which conditions or how much radon reduction will occur. EPA's experience in the 18 Reading Prong homes, as well as that of others, has shown that site and structural conditions in a home ultimately dictate the success or failure of radon mitigation techniques. While EPA's work reduced radon levels in the 18 homes and provided EPA with a better understanding of the problems to be encountered in mitigating indoor radon, it did not demonstrate, at least for the three soil ventilation techniques, that any one technique can be relied on to consistently reduce indoor radon levels. Furthermore, EPA's work has also shown that radon reduction costs vary from home to home and that the cost may be high for some homeowners to reduce indoor radon levels.

Federal Efforts to Address Radon Hazards Emphasize Research and Technical Assistance

Although no unified federal approach exists for dealing with radon problems, several agencies, especially EPA and DOE, are involved in radon-related efforts. EPA is implementing a national strategy that entails conducting research and providing technical assistance and guidance to states and affected homeowners. No direct regulatory program is envisioned. DOE also conducts several types of radon research. Other federal agencies are involved to a lesser extent.

States are also addressing the radon problem. Nine of 19 states we contacted were involved to some degree in addressing radon. State efforts ranged from providing homeowners with information on radon to establishing a loan program to help homeowners finance the installation of radon reduction techniques.

Groups exist at the federal level to coordinate radon activities and efforts have begun. Some inconsistencies in federal policies remain, and it is too soon to judge the effectiveness of coordination efforts.

EPA Is Implementing a Research and Technical Assistance Strategy

In September 1985, EPA developed a strategy for addressing national indoor radon problems. This strategy was inspired by the discovery of high radon concentrations in homes situated along the Reading Prong. EPA's strategy is not proposing a direct regulatory program for radon. Instead, it involves (1) research to characterize the exposure and risks associated with radon and to develop methods for reducing exposure in existing structures and for preventing exposure in future constructions, and (2) providing guidance and leadership to states and the private sector in addressing indoor radon.

In implementing its strategy, EPA plans to initiate a variety of efforts to better define and advise states and homeowners about public exposure to radon, radon's health effects, and ways to reduce indoor radon levels. During fiscal years 1985 and 1986, EPA plans to spend about $4.4 million on radon research and technical assistance efforts. The following are examples of EPA's activities

- In December 1985, EPA began designing a national survey to determine radon levels in residential structures across the country. As discussed in chapter 2, design work will continue through the fall of 1986, with the actual survey expected to begin in July 1987 and be completed in October 1989

- In early 1986, EPA provided the states with drafts of two pamphlets, "A Citizen's Guide to Radon" and "Radon Reduction Methods: A Homeowner's Guide." The pamphlets are designed to help states deal with inquiries from homeowners concerned about radon. EPA expects to issue both pamphlets by July or August 1986.
- In March 1986, EPA announced a training program to improve the capabilities of state personnel in detecting, measuring, and reducing indoor radon. EPA plans to hold about 20 training sessions, with the first one scheduled for mid-June 1986.
- In the summer of 1985, EPA initiated an 18-home project in the Reading Prong area of Pennsylvania to demonstrate the effectiveness of various soil ventilation techniques to reduce indoor radon levels. EPA eventually plans to expand its mitigation research work to about 150 homes across the country.

In addition, EPA has completed or is in the process of (1) outlining procedures to be followed in testing for radon and (2) assessing laboratories' capabilities in conducting radon testing efforts and publishing the results.

DOE Radon Research Activities

Unlike EPA, which channels its radon-related efforts into a single strategy, DOE conducts research directed at specific areas of program interest and responsibility. In particular, DOE conducts radon research as part of its home energy conservation and radiation measurement and health effects programs.

DOE's research is directed toward (1) improving the understanding of the health risks posed by radon exposure through epidemiological and animal studies, (2) understanding and predicting radon sources, pathways, and entry rates into buildings, and (3) developing and evaluating methods to determine radon levels and ways to reduce the levels. During fiscal years 1985 and 1986, DOE plans to spend about $6.4 million on research dedicated to or including radon. The following are examples of DOE's radon work.

- In 1986 DOE began a 5-year study of lung cancers in adult females. The work, involving 2,000 females in central and eastern Pennsylvania, will attempt to assess the relationship between exposure to radon in the domestic environment and the risk of developing lung cancer. Project costs during fiscal year 1986 are expected to total $385,000.

- DOE has a 3-year project underway to study how radon is transported through media, such as soil and concrete, and to improve the use of computer models to predict this movement. Funding for this project during fiscal years 1985 and 1986 will total $145,000.
- In the early 1980's, DOE, concerned that weatherization measures could increase indoor pollutant levels, initiated research to explore ways to control indoor air pollutants. Current efforts include testing, monitoring, and mitigating various indoor air pollutants such as radon, formaldehyde, particulates, and nitrogen dioxide. The mitigation work includes evaluating the effectiveness of ventilation techniques, such as the use of exhaust fans, or air-to-air heat exchangers. Funding for these efforts during fiscal years 1985 and 1986 is expected to total about $2 million.[1]

Other Federal Efforts to Address Radon

In addition to EPA and DOE, several other federal agencies and organizations are addressing radon issues in more limited ways. These include the Department of Housing and Urban Development, the Bonneville Power Administration, the Tennessee Valley Authority, and the National Cancer Institute (NCI). Their activities range from conducting radon research to providing limited financial assistance to homeowners.

Department of Housing and Urban Development

HUD's involvement in indoor radon stems from its interest in assuring that HUD-assisted housing is located in safe and healthful environments. Examples of some of HUD's activities include the following.

- HUD is currently leading and providing technical advice on a demonstration project involving Florida and the U.S. Steel Corporation to test the effectiveness of home construction techniques designed to prohibit radon entry on phosphate lands. Florida contains about 120,000 acres of mined and reclaimed phosphate lands and 300,000 acres of unmined land. According to HUD's Deputy Director for Environmental Planning, construction of the homes is expected to be completed in October 1986 and all testing completed by December 1986. If these construction techniques prove effective and economically feasible, HUD intends to repeal its 1979 decision against insuring housing loans on lands containing phosphate minerals.
- In 1979, when high levels of radon gas were found in the Butte/Anaconda, Montana, area, HUD sponsored research to study the effectiveness of remedial action techniques and provided, through its program to modernize low-income housing, $200,000 to reduce the high radon levels

[1]Includes funding from the Bonneville Power Administration

in a 190-unit public housing complex. In September 1979, HUD also required indoor radon tests for all Butte/Anaconda homes to be purchased with Federal Housing Administration insured loans. In the summer of 1985, HUD dispensed with the testing requirement because homeowners were airing out their houses just before samples were taken, which had the effect of temporarily lowering the radon levels and neutralizing the testing effort. HUD now requires that all prospective buyers in the Butte/Anaconda area be given a disclosure notice that high levels of radon have been found.

Bonneville Power Administration

In 1984, BPA, as part of its Residential Weatherization Program, began a technical assistance and mitigation program designed to alleviate indoor air pollution problems that might result from weatherization efforts. As part of this program, all participants who install BPA-recommended weatherization measures may receive radon tests. If the tests show radon levels above .025 WL, BPA will provide some financial assistance to help a homeowner lower radon concentrations. To date, the only mitigation measure approved for funding is an air-to-air heat exchanger.

Tennessee Valley Authority

TVA is funding a $220,000 survey of radon levels in 60 homes in Alabama, Mississippi, and Tennessee. The survey will evaluate the effect of using phosphate slag (mining wastes) in residential building materials by comparing radon levels in homes built with phosphate slag to homes built without it. The study, which is scheduled for completion in late 1986, will be expanded to include testing mitigation methods if funds become available, according to a TVA project officer.

National Cancer Institute

NCI is sponsoring three lung cancer studies in New Jersey, Sweden, and China that involve radon. NCI's strategy has been to add a radon component to ongoing studies to determine how radon may influence lung cancer. If the results indicate that large-scale studies are required, then NCI will explore the radon problem further. Costs for the radon components of the studies for fiscal years 1985 and 1986 will total $189,000.

State Efforts to Address Radon and State Views of Federal Role

Because a major portion of federal radon activities involves assisting states to make informed decisions about radon, we interviewed radiation and health officials in 19 states concerning their views on federal involvement We also asked about the radon activities states conduct. We found that

- the states' responses generally supported the current research and technical assistance role being pursued by the federal government and
- state activities to address radon ranged from providing information to inform citizens about radon to providing financial assistance to help homeowners alleviate indoor radon hazards.

Although state officials generally supported the current federal role, they differed in their views of what activities should constitute such a role. State responses concerning what the federal role should include varied as follows:

- Conduct radon conferences and symposia for state officials and interested private sector parties to provide for the free exchange of information and experiences (12 states).
- Fund and conduct radon mitigation research (12 states).
- Establish national measurement standards and remedial action guidelines (9 states).
- Establish a national radon testing protocol (7 states).
- Institute a program to evaluate and certify radon detectors and mitigation contractors (6 states).
- Develop a nationwide radon data clearinghouse (5 states).
- Provide financial support for testing homes for radon contamination (5 states).

Nine of the 19 states—Florida, Kentucky, Maine, New Jersey, New York, Oregon, Pennsylvania, Tennessee, and Virginia—have given their residents information about radon Other state efforts to address radon include the following.

- Florida has (1) enacted legislation which gives its state agency authority to establish and enforce environmental standards for radon, (2) formally adopted the 02 WL criterion as a state standard, and (3) prescribed construction techniques for homes built on phosphate lands or other lands with potentially high radiation levels.
- Pennsylvania has established a $2.5 million, low-interest loan program to help homeowners finance the installation of radon reduction techniques

In addition, the 50 states have joined together under the Conference of State Radiation Control Program Directors to coordinate their radon and other radiation activities.

Groups Have Recently Been Established to Coordinate Federal Radon Activities

There have been some recent efforts by federal agencies to coordinate their radon activities. However, it is too early to tell whether these interagency efforts will be successful in assuring that the federal government takes a consistent and well-coordinated approach to addressing indoor radon problems. Despite these initial efforts to coordinate radon activities, some federal radon policies differ and in some cases appear inconsistent.

Radon Coordination Groups Have Been Formed

Concern about the adequacy and coordination of federal radiation programs and policies has existed since 1979 when GAO[2] found that a comprehensive federal and state radiation control program to protect the public from radiation hazards did not exist, and an interagency task force found that there was inadequate coordination of radiation protection among federal agencies. After the reports were issued, President Carter established the Radiation Policy Council in 1980. Because the Council was unable to significantly improve policy coordination, the Committee on Interagency Radiation Research and Policy Coordination was established in April 1984, within the White House Office of Science and Technology Policy.

CIRRPC's overall charge is to coordinate radiation matters among agencies, evaluate radiation research, and provide advice on radiation policy formulation. In February 1985, CIRRPC established a science subpanel on radon protection problems and health effects. The subpanel is to develop a federal consensus on scientific issues regarding environmental radon exposure, with particular emphasis on the magnitude of health risks, the assessment of national exposures, and the state of knowledge regarding radon reduction measures.

Another coordinating group, the Interagency Committee on Indoor Air Quality (CIAQ) was formed in December 1983, in response to concerns expressed about indoor air quality by various national and world organizations and the Congress. The major purpose of CIAQ is to develop a comprehensive research strategy on indoor air quality. Seven work groups were formed, including one dealing with radon and co-chaired by

[2]Radiation Control Programs Provide Limited Protection (HRD-80-25, Dec 4, 1979)

DOE and EPA. In May 1985, the radon working group issued a report calling for (1) a national assessment of radon exposure in structures, (2) development and demonstration of radon reduction techniques, (3) improved radon measurement technologies, and (4) improved information on radon's health effects and estimates of risk. The report also identified priority policy actions that are needed, including determining appropriate roles for federal, state, and local governments, as well as the industrial and private sector, in addressing indoor radon issues.

Federal Radon Policies Inconsistent

Despite current efforts of the two interagency groups to coordinate radon activities, some differences in agency practices exist.

One area of difference is the level where action should be taken to reduce indoor radon levels. EPA is currently developing a citizen's guide that recommends action when radon levels exceed .02 WL. BPA, on the other hand, recommends action when radon levels exceed .025 WL. CIRRPC, which is responsible for providing advice on federal radiation policy, recommends in its June 1986 draft report that a federal consensus on a recommended action level should be established.

Another area where federal policy seems inconsistent is in providing assistance for mitigating high levels of radon. BPA currently provides financial assistance for mitigating high levels of radon to weatherization program participants whose homes have radon levels above .025 WL. This same opportunity does not exist for homeowners who participate in other federally-sponsored weatherization programs, such as DOE's low-income energy assistance program.

Finally, the government's policy on providing financial assistance for housing in areas where radon is a potential problem differs among agencies. HUD currently does not provide insured loans for homes on Florida phosphate lands and requires disclosure notices for homes in the Butte/Anaconda area, but it has no policy for the Reading Prong area. On the other hand, the Farmers Home Administration, within the Department of Agriculture, and the Veterans Administration, which both provide significant housing assistance through insured and guaranteed loans, have no policies regarding radon, according to agency officials.

Conclusions

Overall there is no federal strategy to address radon. Most federal agency efforts to address problems associated with high levels of radon consist of conducting research and providing technical assistance. Generally, the 19 states we contacted supported this approach. Because radon has only recently been recognized as a problem, agencies' programs are evolving and are in various stages of implementation. Similarly, coordination among the various federal agencies is just beginning. CIRRPC and other coordination mechanisms have been established, working groups formed, information is being exchanged, and reports are being prepared. Because coordination efforts are evolving, it is too early to assess their overall effectiveness.

Federal Statutory Authority and Responsibility to Address Indoor Radon Hazards

EPA and DOE are the principal federal agencies that conduct indoor radon research and provide technical assistance. A variety of statutory authorities exist which allow them to carry out these ongoing activities. Although none of these statutes specifically address radon, they do allow EPA to conduct research and provide technical assistance and guidance and they provide DOE with discretionary authority to conduct radon research

Although sufficient authority exists to conduct research-related activities, there is apparently no clear statutory authority or responsibility for the federal government to establish a regulatory control program or to take actions to alleviate indoor radon hazards. The Clean Air Act, which establishes EPA as the lead federal agency responsible for air pollution control, does not provide EPA with a specific legislative requirement to regulate indoor air pollutants, such as radon. Further, our examination of two major federal emergency response and assistance laws, the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) and the Disaster Relief Act, found that neither expressly assigns responsibility or requires federal response action to deal with naturally-occurring indoor radon hazards.

EPA and DOE Have Authority to Conduct Research and Provide Technical Assistance

EPA and DOE are the principal federal agencies that support and conduct indoor radon research and provide guidance and technical assistance to states and affected homeowners. Generally, EPA efforts focus on applied research and its transfer into guidance and technical assistance, while DOE efforts are directed at conducting basic scientific research. Both EPA and DOE operate under a variety of statutes giving them broad authority to conduct these activities

EPA Research Authority

EPA has broad authority under the Clean Air Act to implement its current strategy of radon research, technical assistance, and guidance. Briefly, Section 103 of the Clean Air Act directs the Administrator of EPA to establish a national research and development program for the prevention and control of air pollution, as well as render technical services to other air pollution control agencies and other appropriate public or private agencies, institutions, organizations, and individuals Although Section 103 of the Clean Air Act does not direct or require EPA to establish a research and technical assistance program aimed at addressing indoor radon problems, it provides EPA with broad discretionary authority to implement its radon strategy, as currently conceived.

DOE Research Authority

DOE derives its research authority from several statutes. The Atomic Energy Act, as amended, authorizes DOE to conduct radiation research and development activities, including authority to conduct research on the biological effects of radiation. The Energy Reorganization Act authorizes DOE to engage in environmental, biomedical, physical, and safety research related to developing energy sources and utilization technologies. The Federal Nonnuclear Energy Research and Development Act authorizes DOE to conduct a comprehensive nonnuclear energy research, development, and demonstration program to include the environmental and social consequences of various technologies. Although these statutes and others do not require DOE to address radon, they do, nevertheless, give DOE broad authority to carry out its current radon research activities.

EPA Is Not Mandated by the Clean Air Act to Regulate Indoor Radon Hazards

The Clean Air Act, as amended, establishes EPA as the lead federal agency responsible for air pollution control. Under the act, EPA is charged with the responsibility of administering a regulatory program to control the emissions of hazardous air pollutants. The act requires EPA to establish air quality criteria and national ambient air quality standards for several pollutants which will provide an adequate margin of safety to ensure protection of public health and welfare. Other air pollutants, as designated by EPA, may be regulated if they present a risk of severely harming human health.

Although the Clean Air Act assigns EPA the responsibility and provides authority to regulate a wide variety of hazardous air pollutants, that responsibility does not appear to extend to pollution in the indoor environment. This is an interpretation we previously stated in our 1980 report entitled Indoor Air Pollution: An Emerging Health Problem (CED-80-111). The act's legislative history, which refers to the discharge of pollutants from motor vehicles and industry into the atmosphere, makes it clear that the Congress was addressing pollution occurring in the outdoor "ambient" air. There is no discussion in the legislative history about sources of indoor air pollution or the problem of indoor air pollution. Further, the Clean Air Act requires EPA to establish "ambient" air quality standards, which supports the view that the Clean Air Act is intended to address the problem of external air quality. In its regulations implementing the Clean Air Act, EPA defined "ambient air" as "that portion of the atmosphere, external to buildings, to which the general public has access." Accordingly, EPA has not been given the responsibility under the Clean Air Act to establish an indoor radon regulatory program.

EPA Has Discretionary Authority Under CERCLA to Respond to Indoor Radon Hazards

CERCLA authorizes EPA to respond to the nation's most significant public health and environmental threats from hazardous substances. The National Contingency Plan, which outlines the procedures and situations in which a response action will be taken, provides that CERCLA funds may be used to perform removal or remedial actions at sites where hazardous substances, pollutants, or contaminants are released into the environment. Removal actions are performed to mitigate immediate and significant risk of harm to human life, health, or to the environment and are generally undertaken to mitigate acute situations. Remedial actions consist of long-term, permanent cleanup actions at sites included on the National Priorities List. This list designates the nation's worst known sites contaminated with hazardous substances.

EPA has determined that radionuclides, such as radon, fall under the act's definition of a hazardous substance. Therefore, radon contamination problems may be eligible for a CERCLA response action. However, EPA believes that the act was intended primarily to address environmental problems resulting from human activities. Although EPA has occasionally used CERCLA funds to mitigate high indoor radon levels in homes and other structures, these actions have been taken to alleviate indoor radon exposures at sites contaminated with uranium mining wastes, radium watch dial painting residues, and at other sites associated with uranium and radium processing and manufacturing. As of March 1986, CERCLA had not been used to remediate contamination from naturally-occuring radon sources. EPA's current position is that CERCLA funds will be used to respond only if EPA determines that (1) the release of a hazardous substance or threat of release constitutes a major public health or environmental emergency and (2) no other group has the authority or capability to respond in a timely manner.

Although CERCLA does provide EPA with discretionary authority to respond to a naturally-occurring hazardous substance release, the legislative history does not indicate that the Congress contemplated that CERCLA would be used as a general cleanup authority to mitigate the hazards posed by naturally-occurring substances such as radon. Furthermore, recent bills passed by the House and Senate to reauthorize CERCLA contain language that would explicitly prohibit EPA from using CERCLA funds to respond to naturally-occurring releases of hazardous substances, except where the President determines that the release is an environmental or public-health emergency.

FEMA May Have Authority Under the Disaster Relief Act to Respond to a Radon Emergency or Disaster

The Federal Emergency Mangement Agency (FEMA) is accorded a broad role in civil emergency planning, management, mitigation, and assistance. FEMA's principal response authority is the Disaster Relief Act of 1974, which authorizes a broad range of federal response activities if the President declares an emergency or a major disaster resulting from events specified in the act.

We concur with FEMA's opinion that the Disaster Relief Act, as amended, potentially could be used by the President to respond to a disaster caused by radon. Indoor radon hazards might constitute a disaster or emergency under Section 102 of the act. However, response or assistance would be contingent upon a number of factors and determinations. The governor of an affected state would have to determine that the disaster or emergency was beyond local and state capabilities and request federal assistance. If such a request is made, the President could make an "emergency" declaration, upon concluding that federal emergency assistance was necessary ". . . to supplement state and local efforts to save lives and protect property, public health and safety or to avert or lessen the threat of a disaster." The President could also make a "major disaster" declaration upon determining that there exists ". . . damage of sufficient severity and magnitude to warrant major disaster assistance under the Act." Situations that would support an "emergency" or "major disaster" declaration are not specifically defined in the act, but such declarations are generally made at the discretion of the President.

Although FEMA could potentially respond to an emergency or disaster caused by radon if the President makes an "emergency" or "major disaster" declaration, no governor, as of March 1986, had requested assistance under the Disaster Relief Act. According to a legal interpretation made by FEMA's General Counsel on September 12, 1985, FEMA does not have a sufficient body of knowledge as to the nature of the health threat, the extent of the problem, and a recommended solution to determine if federal response under the Disaster Relief Act would be appropriate.

Conclusions

EPA and DOE, as well as other federal agencies, conduct numerous activities designed to address the problems associated with indoor radon. These activities generally entail conducting research and providing technical assistance and guidance to affected homeowners. These efforts, for the most part, are being conducted under a variety of broad research-related statutes and authorities. Of the agencies we reviewed, all appear to have sufficient statutory authority to conduct their ongoing efforts.

However, there does not appear to be any clear statutory authority or responsibility for the federal government to establish a radon regulatory control program or to take actions to alleviate indoor radon hazards. There also is apparently no clear statutory authority for the federal government to provide financial assistance to help states and affected homeowners respond to radon problems.

Although the federal agencies we reviewed all appear to have sufficient statutory authority to conduct their ongoing radon efforts, it is important to note that these efforts are being conducted at the discretion of each individual agency. None of the enabling statutes we reviewed explicitly mandates or requires that radon research, technical assistance, guidance, or other assistance be provided.

Not only are these agencies not required by statute to address indoor radon problems, but their ongoing radon activities are all being conducted autonomously. There is no formally designated agency or organization responsible for assuring that (1) radon research efforts do not overlap, (2) radon research is being conducted on the most significant issues, and (3) the federal government is operating under and recommending consistent radon policies and guidance. Although some interagency groups have recently been established to facilitate radon research and policy coordination, it is too early to assess whether these efforts will be successful in assuring that the federal government takes a consistent and well-coordinated approach to addressing indoor radon problems.

Radon was one of the major pollutants discussed in our 1980 report Indoor Air Pollution: An Emerging Health Problem (CED-80-111), which evaluated the federal government's efforts to deal with the general problem of indoor air pollution. In that report we suggested that EPA should be given responsibility for indoor air quality. This suggestion was based on our observation that federal efforts to address indoor air pollutants were at that time not effective because no one agency was clearly responsible for the issue Although our current review did not evaluate federal efforts to address the broad range of indoor air pollutants, the current federal response to the indoor radon problem suggests that EPA should still be given responsibility for indoor radon EPA has responsibility for outdoor air pollution problems, and other agencies look to EPA for guidance and leadership on the indoor radon issue.

Matters for Consideration by the Congress

Although a number of federal interagency groups have recently been established to facilitate the coordination of radon research and policies, it is too early to assess whether these efforts will be successful in assuring that the federal government takes a unified, consistent, and well-coordinated approach to addressing indoor radon problems. Even if such federal coordination efforts prove successful, the Congress may wish to designate, in the interest of prudent oversight and clear accountability, one federal agency responsible for federal radon efforts. Because EPA is carrying out much of the current radon work and is implementing a comprehensive strategy to address radon throughout the nation, it would be the logical agency to choose for such a responsibility. To accomplish this, the Congress could either amend the Clean Air Act to give EPA responsibility for indoor air pollution, or enact other legislation.

Should the Congress decide to make a federal agency, such as EPA, responsible for overseeing federal radon efforts, it may also wish to stipulate the specific activities to be conducted, such as performing research, providing technical assistance, establishing regulations, or providing financial assistance. Again, this could be accomplished by amending existing legislation or enacting new legislation.

Members of Pennsylvania Congressional Delegation

The Honorable Joseph M. Gaydos

The Honorable Gus Yatron

The Honorable John P. Murtha

The Honorable Joseph M. McDade

The Honorable R. Lawrence Coughlin

The Honorable Robert A. Borski

The Honorable William F. Clinger

The Honorable William J. Coyne

The Honorable Robert W. Edgar

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The Honorable George Gekas

The Honorable William F. Goodling

The Honorable William H. Gray, III

The Honorable Paul E. Kanjorski

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The Honorable Peter H. Kostmayer

The Honorable Austin J. Murphy

The Honorable Thomas J. Ridge

The Honorable Donald Ritter

The Honorable Richard T. Schulze

The Honorable Bud Shuster

The Honorable Doug Walgren

The Honorable Robert S. Walker

Indoor Radon Measurement Results by State as Reported by Terradex

State	Number of measurements	Radon levels (pCi/l) Median	Radon levels (pCi/l) Average	Percent over 4 pCi/l[a]
Alaska	21	2 82	4 30	38 1
Alabama	54	1 47	2 28	18 5
Arkansas	4	3 37	4 29	50 0
Arizona	86	66	6 78	19 8
California	519	70	1 37	3 9
Colorado	165	3 33	16 31	38 8
Connecticut	89	1 89	2 55	16 9
Delaware	27	93	1 58	7 4
District of Columbia	32	81	6 43	18 7
Florida	198	1 24	5 95	16 7
Georgia	46	99	2 31	15 2
Hawaii	1	•	36	0 0
Idaho	463	2 83	5 88	39 1
Illinois	116	1 59	2 25	18 1
Indiana	32	1 58	3 04	28 1
Iowa	63	2 24	3 11	31 7
Kansas	12	1 97	4 59	25 0
Kentucky	58	1 28	2 52	12 1
Louisiana	24	62	97	4 2
Maine	1,337	1 71	13 19	24 5
Maryland	65	2 23	4 28	20 0
Massachusetts	136	1 65	2 49	15 4
Michigan	71	1 58	3 06	19 7
Minnesota	175	3 37	11 22	45 1
Mississippi	10	1 22	1 26	0 0
Missouri	39	64	1 37	7 7
Montana	235	2 99	4 50	32 8
Nebraska	12	2 64	5 02	33 3
Nevada	308	1 56	4 49	14 3
New Hampshire	46	3 49	7 84	43 5
New Jersey	2,217	1 96	5 23	25 9
New Mexico	533	2 03	4 26	26 6
New York	2,294	1 25	2 63	14 8
North Carolina	27	1 34	1 73	7 4
North Dakota	37	2 08	3 91	21 6
Ohio	341	2 96	4 78	36 7
Oklahoma	11	95	1 34	0 0
Oregon	3,236	74	1 19	4 3
Pennsylvania	14,968	5 05	15 07	57 9
Rhode Island	7	64	22 95	14 3

South Carolina	15	70	1 25	6 7
South Dakota	603	2 29	6 67	28 4
Tennessee	430	2.03	3 33	28.6
Texas	441	58	74	2
Utah	27	1 98	2 83	13 5
Virginia	169	77	2 24	13 0
Washington	7,972	54	1.01	3 3
West Virginia	11	63	7 64	18 2
Wisconsin	192	1 85	2 45	17 7
Wyoming	116	4 55	14 24	52 6
East Coast[b]	231	2.35	7 13	30 7
Northwest[b]	935	1 05	2 30	12 2
U.S.	**39,536[c]**	**1.83**	**7.73**	**30.3**

[a]Equivalent to 02 WL

[b]Designation by Terradex for those measurements where state was not identified in Terradex records

[c]Total includes 218 radon measurements for which Terradex was unable to categorize by state or region

Glossary

Air Exchange Rate	The rate at which fresh air coming into a home completely replaces the home's existing air supply.
Air Filtration	A radon reduction technique in which air is passed through high efficiency filters or electronic devices. The devices collect dust and other airborne materials to which radon particles attach themselves.
Air-To-Air Heat Exchanger	A ventilation device used to reduce radon levels in homes by retaining indoor heat while exchanging indoor air and accompanying pollutants for fresh, outdoor air.
Basement Pressurization	A radon reduction technique in which air pressure in a basement is increased in order to raise the basement's air pressure above that of the soil beneath and around a home.
Charcoal Canister	A radon measurement device that functions by absorbing dust and accompanying radon.
Drain Tile Ventilation	A radon reduction technique in which radon is drawn away from a home via an underground drainage system surrounding the home at the basement floor level. Drain tile ventilation is one of several soil ventilation techniques.
General Sealing	Radon reduction techniques that involve placing barriers between the radon source and the living space in a home. Techniques include sealing cracks in concrete floors and walls and filling concrete block walls.
Home Ventilation	A radon reduction technique in which a home's existing indoor air supply is replaced by fresh, outdoor air. Structural ventilation may be done naturally (by opening windows or vents) or mechanically (by using fans).
Phosphate Slag	Waste materials from phosphate mining, sometimes used as foundation material in construction work. Phosphate is often laced with radon-producing uranium.

PicoCuries Per Liter (pCi/l)	A unit of measure used for expressing levels of radon gas.
Radon	A colorless, odorless gas produced by the natural decay of radium in soils and rocks.
Reading Prong	A geological formation extending through New Jersey, New York, and Pennsylvania where high levels of naturally-occurring radon have been found.
Soil Ventilation	A radon reduction technique in which radon is drawn away, or ventilated, from a home before it can enter. Several types of soil ventilation exist.
Sub-Slab Ventilation	A radon reduction technique in which pipes are placed into the stone aggregate beneath a home's basement floor to ventilate radon. Sub-slab ventilation is one of several soil ventilation techniques.
Wall Ventilation	A radon reduction technique in which the network of openings within a home's concrete block walls is ventilated. Wall ventilation is a type of soil ventilation.
Working Level (WL)	A unit of measure for documenting exposure to radon decay products. One WL is equal to approximately 200 pCi/l.
Working Level Month (WLM)	A unit of measure used for measuring cumulative exposure to radon. One WLM equals exposure to one WL for 173 hours.

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