Experts Debate Cost/Benefit Analysis and Epidemiologic Studies

EPA Guideline for Indoor Radon Levels Evokes Response from Nuclear Medicine

"There really needs to be some kind of cost/benefit analysis. We need to determine how many lung cancers will be prevented by such a program, and compare it with how many lives could be saved if that money were spent in other ways."

When the United States (US) Environmental Protection Agency (EPA) held a press conference about radon on August 14, 1986, the news media galvanized the public into awareness of a potential indoor pollution problem that radiation experts have acknowledged for years. "Radon is probably the biggest public health problem we have," said Richard Guimond, director of the EPA's Radon Action Program.

James J. Conway, MD, director of the Nuclear Medicine Department at the Children's Memorial Hospital in Chicago, Illinois, said that his department received a number of telephone calls from people concerned about radon. "I was concerned about this announcement by the EPA and the media. It was causing just one more instance of radiation hysteria when, at least in the Chicago area, there is no definite proof that any significant hazard exists," said Dr. Conway, who is also a member of the International Commission on Radiological Protection (ICRP) committee that addresses medical risks of radiation.

In its publication, "A Citizen's Guide to Radon: What It Is and What to Do," the EPA recommends that homeowners who find 4 pCi/l or more of radon in their houses take action to reduce that level. The agency estimates that 5,000–20,000 of the 130,000 total lung cancer deaths each year in the US may ultimately be attributed to radon. According to the EPA, as many as 8 million dwellings in the US may exceed the guideline of 4 pCi/l.

The EPA's attack on indoor radon inspired newspaper headlines ranging from "The Victims of Nature" (*Medical Tribune*, Sept. 24, 1986) to "Media's Radon Scare Is 99% Baloney" (*USA Today*, Aug. 21, 1986). It has generated criticism from some radiation experts and praise from others.

Economic Impact

Radon reduction methods are relatively inexpensive, according to the EPA, and range in cost from $150–$5,000. Radon detectors cost about $10–$50. Millions of homes may be affected, however, "and the economic impact is phenomenal," said one radon scientist.

"There really should be some kind of cost/benefit analysis," said Edward W. Webster, PhD, director of the Division of Radiological Sciences and Technology at Massachusetts General Hospital in Boston. "If there are 8 million homes exceeding the EPA's recommended limit for radon concentration, and if it costs $2,000, for example, to reduce the radon level in each home, that's $16 billion of the gross national product. We need to determine how many lung cancers will be prevented by such a program, and compare it with how many lives could be saved if that money were spent in other ways," said Dr. Webster, who is also a member of The Society of Nuclear Medicine (SNM) Committee on Biologic Effects of Ionizing Radiation.

Mr. Guimond estimates that reducing all homes in the US to 4 pCi/l would save 2,000–8,000 lives lost each year to lung cancer. Some EPA critics believe that the money needed to modify the 8 million homes that exceed 4 pCi/l could save more lives if spent on other programs, such as antismoking campaigns.

Dr. Conway said that he is concerned about the segment of the population that is overly fearful of radiation at any level. "I don't know what is gained by upsetting these people. If a radon problem exists in a certain region, the EPA should prove that homes in that area have excessive levels of radon, and then send notices to those homeowners. That strategy would have been more constructive than issuing a blanket statement that radon will kill 20,000 people this year

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in the US, which cannot be proven," he explained. The way this information was released "was pure, unadulterated media hype, which leads to radiation hysteria, and which can be more harmful that the radon itself," said Dr. Conway.

Mr. Guimond, a health physicist, expressed concern over the possibility that the EPA Radon Action Program caused undue alarm over radiation in general, and said that he would welcome any suggestions from the nuclear medicine community on better ways to communicate radiation risk to the public. "We also cannot control how the media handle stories about radiation," he added.

With regard to the lack of scientific proof for the number of people who die from radon, Mr. Guimond said, "Any time you have a disease, such as lung cancer, with several causative factors, it's hard to single out one factor and determine how many deaths it causes. The potential of saving thousands of lives, however, even though that number is calculated theoretically, justifies the EPA's efforts to reduce the public's radon exposure."

Engineer at Nuclear Power Plant Set Off Alarms

An event that occurred on December 19, 1984, led to the EPA Radon Action Program and last summer's ground swell of media attention on radon. Stanley J. Watras, an engineer at the Limerick Nuclear Power Station in Pennsylvania, set off radiation detector alarms as he reported for work that day. His contamination was traced to radon gas and radon progeny in his home at the highest concentration ever measured indoors—2,700 pCi/l or 13.5 working levels (WL). "My estimated yearly exposure to the lungs was 10,000 rem," Mr. Watras told *Newsline*. [The cumulative yearly exposure from the EPA's recommended level of 4 pCi/l (0.02 WL) is an estimated 10 rem to the lungs.]

Stanley J. Watras, the nuclear power plant engineer who discovered that the radon concentration in his house was 2,700 pCi/l (13.5 WL), with his wife, Diane, and children, Michael, Christopher, and Cynthia. Mr. Watras said that he is a strong advocate of nuclear power, and he believes that the public needs more education on risk perception and nuclear technology. "The radiation exposure I received in 12 years as a nuclear worker was 1,000–2,000 times less than the exposures received by my family in the one year we lived in our house," he said.

(Courtesy of the Reading Eagle Co.)

Mr. Watras applauds the EPA's strategy for reducing radon risk. "We're talking about the lives and welfare of the general public, and we have to take the most conservative approach and use the worst-case assumptions," he said.

Radon and Physicians

Although the public usually perceives radon as an environmental issue, it has become a medical issue as well because the public wants information about the health risks. As one radon expert pointed out: "What was the first thing Stanley Watras did after he learned that his house was highly contaminated with radon? He called a physician." These calls are often directed to the nuclear medicine community.

After first contacting their pediatrician, Mr. Watras and his wife, Diane, consulted with numerous physicians about the health consequences of the radon exposures received by them and their three children. "We repeatedly heard 'I don't know' from doctors when we asked about the health risks, and that was truly emotionally damaging for me and my wife," said Mr. Watras. "When they tried to find the answer, they came up with the same thing everyone else comes up with—mathematic speculations."

Eventually, Mr. and Mrs. Watras were referred to Roger E. Linnemann, MD, chairman of the Radiation Management Corp. in Philadelphia. "He explained to us that we received the highest known radiation doses through natural means, and that nothing exists that can determine the damage or counteract it. He also said that if we worry every single day about dying in the near future, we *will* die in the near future—from psychosomatic illnesses or nervous disor-

ders. That made a lot of sense to us at that time, and it calmed us down enough so that we could decide how to handle the situation in a rational manner," said Mr. Watras.

The first immediate countermeasures he took were quitting cigarette smoking and moving his family to a different house. For the past 2½ years, Mr. Watras has devoted much of his time to what he calls a crusade for more epidemiologic and radiobiologic research on the effects of radon exposure. He is the chairman of the Health Subcommittee to the Radon Advisory Committee of the Pennsylvania Department of Environmental Resources (PA-DER). The goal of this committee is to persuade large medical organizations and research institutions to acknowledge publicly that radon is "a potential killer," and then use this leverage to obtain more funding for research on radon's health effects.

From Mr. Watras's perspective, environmental groups and the housing industry have taken measures to deal with the radon problem, but the biomedical research community seems to need more convincing. He has studied the sources of medical research funding, and testified before federal and state legislators in support of increased funds for radon research. "I think this problem deserves the same kind of commitment of resources as the war on cancer and the search for a cure for AIDS [acquired immunodeficiency syndrome]. It's possible that exposure to radon is not as dangerous as it is perceived today. Perhaps the data will show that it's actually beneficial. But until some more thorough, prospective epidemiologic studies are completed, we have to assume the worst and hope for the best," said Mr. Watras, adding that he hopes that acquiring more data will eliminate the need to rely so heavily on mathematic theories based on several debatable assumptions.

Dr. Linnemann, who is also a professor of radiological sciences at the University of Pennsylvania, said that, in general, physicians should learn about cancer statistics, particularly lung cancer, and help patients understand the risks and benefits of radiation. "Nuclear medicine physicians should also be aware of the EPA standards, and be able to advise patients on how to have radon levels measured in their homes," he added.

Dr. Conway explained how he handles questions about radon: "I tell my patients that the numbers for lung cancer deaths are purely conjectural, and I emphasize that they are theoretic derivations of the worst situation that can possibly exist. I also explain that many factors—not just radiation—enter into carcinogenesis. Some frightened individuals, though, are still not consoled by this type of information."

A. Bertrand Brill, MD, PhD, director of the Division of Nuclear Medicine at Brookhaven National Laboratory in Upton, New York, said that he tries to dissuade people from panicking. "Even if we assume that the EPA's risk estimates are correct, I point out that homeowners can take measures to modify that risk," said Dr. Brill, who is also chairman of the SNM Committee on Biologic Effects of Ionizing Radiation.

The EPA receives frequent calls from homeowners who find radon levels above the 4 pCi/l guideline, and who want to know their chances of dying from lung cancer. Daniel Egan, of the EPA's Radon Action Program, said that if he were asked this question, he would want to know more about the basis for concern and he would recommend additional radon measurements. "Very often the exposure to radon decay products is not significantly high, and residents may not have been exposed for a long period of time," he added.

"Once physicians become articulate with the risks, they can help their patients decide what those risks mean to them," said Stephany DeScisciolo, special assistant to the director of the EPA's Radon Action Program. "People feel more reassured when someone they consider an expert tries to 'walk them through' the problem personally," she said.

Establishing Action Levels

Radon poses a number of regulatory problems. Unlike situations involving industrial pollutants, where factories that allegedly create the hazard can be forced to comply with standards, radon occurs naturally. "You're dealing with millions of individual homeowners who have made major investments. Some real estate agencies are insisting on radon measurements because they're afraid of liability. No one really wants to regulate the environment inside people's homes, so radon will be controlled, in essence, by the housing market," said James Stebbings, ScD, epidemiology group leader at Argonne National Laboratory in Illinois.

Several federal agencies in the US are involved in the radon issue (*1*). The Department of Energy (DOE) has sponsored radon research since the 1950s. The Bureau of Standards sets standards for energy efficiency, which could affect ventilation and, in turn, concentrations of radon gas in homes. Similarly, housing construction, which involves the Department of Housing and Urban Development, can affect radon levels. In addition, the Nuclear Regulatory Commission (NRC) and the Departments of Labor, Commerce, Health and Human Services, and the Interior have interests in the regulation of radon.

All estimates of lung cancer caused by radon are based on data from miners who were occupationally exposed to radon gas. Experts disagree on how to adapt the miner data to home exposures, how to calculate the risk factor per unit of exposure,

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and how cigarette smoking in combination with radon exposure affects lung cancer risk.

EPA Risk Estimates

The EPA first became involved in setting standards for radon levels in 1972 when uranium mill tailings were used as backfill under houses in Grand Junction, Colorado. In 1976, the EPA became concerned about radon in houses built on reclaimed phosphate-mined land.

According to Mr. Guimond, "It wasn't discovered until the late 1970s or early 1980s that homes without any connection to mining contained high levels of radon. When Stanley Watras's home was found to have such high levels, 10 times higher than most houses contaminated from uranium mill tailings, we realized that the problem was probably 100 times bigger than we had envisioned."

Some EPA critics point out that the agency's risk estimates are based on extrapolations from high to low levels of exposure, which makes the validity of those risk estimates questionable. According to Mr. Guimond, however, data show that cumulative exposures for miners span a wide range, from 10 to 10,000 working level months per year (WLM/y), and that miners in the 100–10,000 WLM/y range demonstrated a statistically significant increase in lung cancer. Radon exposures in many homes are also found within that range, "so the data we use are not extrapolated from high- to low-exposure levels," explained Mr. Guimond. (The potential alpha particle energy release from 1 WL of radon progeny is 1.3×10^5 MeV per liter of air.)

Dr. Brill of Brookhaven pointed out that since the alpha-emitting radon daughters are characterized by high linear-energy-transfer (LET) radiations, the dose/response curve is linear. It is not as difficult to extrapolate from high to low doses for high LET particles as it is for low LET radiations, he explained.

In adapting the miner data to the general population, however, the EPA did make certain assumptions: radon is the only factor associated with increased lung cancer risk in miners; the risk per unit of exposure is the same in men as in women and children (the miner data are collected from adult men at similar exposure levels); risk is proportional to the amount of radon daughters deposited in the airways, and therefore to the amount inhaled and to lung size; interaction between radon daughter exposure and cigarette smoking is the same throughout the general population; the risk factors assigned at occupational levels are valid at the generally lower level of home exposures.

Ideal Goal—Zero Risk

The EPA did not establish its standard of 0.02 WL (4 pCi/l) for indoor radon concentration by determining an acceptable level of risk for the population. Instead, the EPA took the approach of assuming that the most desirable outcome would be to reduce radon exposure as much as possible within the limits of available technology and economic considerations. "Our ideal goal would have been to reduce the risk to almost zero. We realized that this would require reducing indoor radon levels to the value of outdoor levels, or even lower in some cases," said Mr. Guimond.

The health risks at 4 pCi/l are still "fairly significant, posing an approximate 2% risk of lung cancer for lifetime exposure," noted Mr. Guimond. The general public, however, most likely assumes that the widely publicized 4 pCi/l is based on health risk. In addition, the public often misunderstands the relative risks associated with such safety standards, and mistakenly assumes that 4 pCi/l represents the dividing line between safe and unsafe levels of radon.

Dosimetry for radon is generally agreed upon among radiation experts. Some, however, question the EPA's range of risk per WL exposure. According to Ralph Wilde, section leader of the Policy and Procedures Section at the NRC, "the problem with a WLM, as it was defined for a miner, is that it simply addressed concentration, but other factors such as breathing rate also affect exposure levels." Mr. Wilde also questioned the validity of the assumption for the amount of time that US citizens spend in their homes. (The EPA uses the assumption that people spend 75% of their time at home over a 70-year lifetime.)

Mr. Wilde, who has 30 years of experience in radon issues, contends that the cumulative exposure from 1 WL (200 pCi/l) is closer to 20 WLM/y, rather than the 50 WLM/y calculated by the EPA. The resulting action level could then be higher (10 rather that 4 pCi/l), significantly reducing the number of affected homeowners.

Naomi H. Harley, PhD, of the Department of Environmental Medicine at New York University, disagrees with Mr. Wilde's views on breathing rate. During work hours, miners generally have a faster breathing rate than people at home, where significant time is spent relaxing or sleeping. The deposition rate, though, of radon daughters (solid particles often attached to airborne dust) in the lungs depends on airstream velocity, said Dr. Harley. The lung deposition rate of radon progeny, therefore, is lower when the breathing rate is higher because the particles spend less time in the bronchial airways, she explained. "These rates can be calculated quite exactly. Futhermore, a small percentage of radon daughters do not attach to other particles in the air, and this percentage has a more efficient deposition in the lungs, introducing another factor to dose estimation," added Dr. Harley, who was a member of the

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National Council on Radiation Protection and Measurements (NCRP) Scientific Committee 73, which prepared Report No. 77, "Exposures from the Uranium Series with Emphasis on Radon and Its Daughters" (*2*). Dr. Harley also chaired the NCRP committee that prepared Report No. 78, "Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States" (*3*).

According to Dr. Harley, the factors of breathing rate and whether radon progeny are attached to airborne particles in effect cancel each other out in dose estimation. "A uranium miner and a person relaxing at home do receive the same radiation exposure from radon if the concentrations are the same in both environments."

Dr. Harley still disagrees with EPA's guideline of 4 pCi/l, however, for other reasons. "The EPA looks at the highest estimates derived from the miner data," she stated. In particular, Dr. Harley cites the EPA's risk estimate of 44–77% lung cancer mortality for exposure to radon concentrations of 200 pCi/l over 70 years. "There are no data at all to support that range of estimated risk. Studies of miners in Austria and Czechoslovakia, for example, demonstrated that working environments of more than 2,000 pCi/l were associated with, at most, a 50% mortality rate (*4*). I think that the EPA's upper bound of 77% lung cancer mortality at 200 pCi/l is five times higher than it should be," explained Dr. Harley.

[The EPA recommends that homeowners who find 200 pCi/l or more in their dwellings "take action within several weeks" to reduce levels as far below 1.0 WL (200 pCi/l) as possible. "If this is not possible, you should determine, in consultation with appropriate state or local health or radiation protection officials, if temporary relocation is appropriate until the levels can be reduced." At 4–20 pCi/l, the EPA recommends that homeowners perform follow-up measurements with year-long detectors, and measures to reduce radon concentration should be taken "within a few years."]

Cigarette Smoking and Radon

Studies indicate that 100,000 of the 130,000 annual lung cancer deaths in the US are caused by cigarette smoking. Whether the combined effect of cigarette smoking and radon is additive or multiplicative is still a matter of controversy. "Nobody quite knows, but as mining data are examined more closely, the effect seems to be slightly more than additive," according to Dr. Harley.

Jacob I. Fabrikant, PhD, chairman of the fourth Committee on the Biological Effects of Ionizing Radiations (the BEIR IV Committee), established by the National Academy of Sciences (NAS), said that this committee based its risk projections on a multiplicative interaction between radon daughter exposure and smoking, although it recognized that a "less-than-multiplicative model" is also consistent with the data.

The relationship between radon and smoking is complicated by the dosimetry of the alpha particles emitted by radon daughters. According to Mr. Wilde, it's not certain which cells in the bronchial tree are target cells, or what quality factor to assign an alpha particle.

Dr. Harley, however, believes that the dosimetry is not extremely difficult, but it involves modeling with about 10 factors entered into the calculation. "All of the factors are based on measured quantities, such as particle size and breathing rate—they are not guesses," she added.

EPA Follows Precedent

The EPA's guideline of 4 pCi/l is not new. The same action level has been mandated in the past by the US federal government. In 1972, the surgeon general of the US Public Health Service established 4 pCi/l as the action level for decontaminating homes exposed to uranium mill tailings in Grand Junction, Colorado. ("The money spent per lung cancer to clean up these mill tailings was absolutely disproportionate to anything reasonable," commented Dr. Harley.)

Four years later, the EPA recommended the same level for reclaimed phosphate-mined land in Florida. Some radon experts believe that it would be politically unwise for the EPA to recommend a different level now to the public. "If they change the number now, they are admitting that what was done in the past may have been wrong," said one scientist.

According to Ms. DeScisciolo of the EPA's Radon Action Program, the miner data were reviewed by the EPA's Science Advisory Board, which then approved a range of risk estimates. This board advises the EPA on a variety of issues. A subgroup, the Radiation Advisory Committee, was also consulted on the radon guidelines.

Dr. Harley contends that the Science Advisory Board essentially "rubber-stamped" the EPA's previous risk estimates. Although the advisory board "is a knowledgeable group, they were not considering the consequence of the risk estimates. The projected risks have to fit both the miner data and the observed lung cancers in environmentally exposed nonsmokers. The lower value of the EPA estimated risk range would attribute all nonsmoker lung cancers to radon, and the upper value of the EPA risk range is totally unreasonable," said Dr. Harley. With most other carcinogens, there are no human data, and standards are set based on animal studies involving "huge doses, which is very unrealistic," said Dr. Harley. The advisory board dealt with radon the same way they would deal with other carcinogens, by going

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Soil samples from proposed building sites can be evaluated to determine radon concentrations by using a low-level beta detector (above) to measure the content of lead-210, a decay product of uranium.

(Courtesy of Teledyne, Inc.)

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along with overly conservative action levels. "Radon is different, though, because there are human data for exposures that are found naturally in the environment," explained Dr. Harley.

Seymour Jablon, a member of the Radiation Advisory Committee, said that this committee was asked "some questions about radon, such as what kinds of risks one would associate with given levels of exposure, and we reviewed one proposed study. But that's the sum and substance of it."

Although the EPA consulted other government agencies when it was developing its radon action level, some scientists representing those agencies feel that their advice was ignored. The DOE has continuous radon research experience from the initiation of mine measurements of radon concentration in 1951 up to current epidemiologic studies and projects on the interaction between buildings and soil. Two DOE offices, the Office of Health and Environmental Research and the Office of Energy Conservation, will fund over $10 million of radon research over the next year. According to one DOE radon scientist, the DOE felt that it was a mistake to choose an action level of 4 pCi/l because of the great uncertainties and economic impacts. A higher level, with more emphasis on a graded response to various levels of radon concentration, might have been more realistic.

The EPA contends that the DOE's suggestions were considered. Rather than abandon the Science Advisory Board's range of risk estimates, however, the EPA "chose to clarify the origins of its estimates and include a discussion of the uncertainties associated with all estimates of risk from radon exposure" in its brochure, "A Citizen's Guide to Radon," according to testimony given before a congressional committee. Consequently, the section headed, "How certain are scientists of the risks?" explains that "radon risk estimates are based on scientific studies of miners exposed to varying levels of radon in their work underground," and that to account for the uncertainty in these numbers, scientists generally express risk associated with exposure to a particular level as a *range* of numbers." (The fact that the EPA's range was questioned is not mentioned.)

The Committee on Interagency Radiation Research and Policy Coordination (CIRRPC) of the US Office of Science and Technology Policy (OSTP) also evaluated radon risk. It set out in February 1985 to "develop a basis for a federal consensus on environmental radon exposures" (*1*). Eight federal agencies, including the EPA, were represented on the Radon Science Subpanel, which published its recommendations in August 1986—the same month that the EPA published its radon brochure.

Mr. Wilde, the NRC representative to CIRRPC and a member of the Radon Science Subpanel, pointed out that CIRRPC was not tasked with setting a standard, and that the EPA was not required to follow CIRRPC's advice. He suggested, though, that CIRRPC "was overtaken by events," as its report was finished barely in time for the EPA to look at it before its radon brochure was published. The CIRRPC Science Subpanel, like DOE, advocated a graded response to indoor radon rather than a single action level.

A subcommittee of the US House Committee on Science, Space, and Technology, chaired by congressman James H. Scheuer (D-NY), has questioned why the EPA Radon Action Program is not part of the EPA Indoor Air Program.

According to the EPA, its Radon Action Program was set up under the Office of Radiation Programs (which is under the EPA Office of Air and Radiation) because "the problem was urgent and the expertise to deal with it already existed there." Other indoor air quality problems are managed by the EPA Office of Program Development (OPD). The OPD's research plans are provided to the interagency Committee on Indoor Air Quality, which also is kept informed of the

DOE's radon research program. Although the Committee on Indoor Air Quality has a Radon Workgroup, cochaired by EPA and DOE representatives, the EPA Radon Action Program does not report directly to that interagency committee. Some radon experts believe that the EPA has insulated its Radon Action Program from interagency review by separating it from the EPA Indoor Air Program, and by relying on previously established risk estimates.

The EPA's radon action level of 4 pCi/l (0.02 WL) is lower than action levels recommended by internationally recognized radiation protection bodies. The NCRP recommends 8 pCi/l, and the International Commission on Radiological Protection (ICRP) recommends 10.8 pCi/l (0.054 WL). In Sweden, 400 Bq/m^3 (11 pCi/l) is the action level for existing homes, but 75 Bq/m^3 (2 pCi/l) is the target level for new homes. Both Canada and the United Kingdom have established 20 pCi/l as their radon action levels.

Epidemiologic Studies

• *Maine:* A collaborative pilot case-control study began four years ago, involving the Research Department of the Maine Medical Center in Portland, the Physics Department of the University of Maine, and the Maine Department of Health and Human Services.

The initial concern was radon found in the water supply. According to Peter Rand, MD, director of the Research Department at the Maine Medical Center, the study population uses water from drilled wells, and includes 100 incident lung cancer cases, 150 cases of other types of cancer, and 250 controls. The study, which is nearly complete, is also funded by the Maine Cancer Society and the Maine Lung Association, and various other contributors.

Air radon was measured in kitchens by track etch detectors left for three months. The lung cancer cases were determined by hospital pathology reports throughout the state. Male and female participants in the study filled out a questionnaire that evaluated active and passive smoking history, occupational exposure, a short medical history, and household characteristics. Dr. Rand said that interesting connections are being drawn between radon levels and household characteristics, including the structure of the foundation, the cellar floor, the type of heating, water use, and the location of the house in relation to geologic features.

A more extensive project is also in the works. "In the process of doing this study, the EPA became interested and asked us to consider expanding it, and to get more definitive results," said Dr. Rand. The study will include all incident lung cancer cases in Maine and New Hampshire, and measurements of household radon concentrations in air and water.

These activated charcoal canisters have been exposed for four days to the air inside various buildings being tested for radon levels. A scintillation detector can be used to measure the gamma radiation generated by radon daughter products. **(Courtesy of Teledyne, Inc.)**

• *Pennsylvania:* The Reading Prong area of eastern Pennsylvania was one of the first to discover high radon levels in homes. Last October, the Argonne National Laboratory in Illinois began a series of case-control studies of decedent lung cancer cases in women who lived in eastern and central Pennsylvania. The first series of 100 women is currently being studied.

Collecting the vital statistics was the first thrust of the project, according to Dr. Stebbings, epidemiology group leader. "We have records on over 6,200 female deaths, and we are working toward several case series of about 500 cases each," said Dr. Stebbings. The controls will be randomly selected population controls.

The study focuses on women because, compared with men, they are more likely to spend more time at home, they are less likely to have interfering occupational exposures, and fewer women smoke cigarettes.

Dr. Stebbings emphasized the importance of looking at the cell type of cancer. "There's little evidence that adenocarcinomas have been induced by radon; yet in nonsmoking women, that's roughly half of all lung cancers. Small-cell carcinomas are rarely found in nonsmokers, and yet they were an early effect of radon in miners, although predominantly among smoking miners," he explained. (The Maine study is also classifying lung cancer cases by cell type.)

Radon in homes will be measured by both year-long detectors and grab samples. Although less accurate than longer measurements with track etch detectors, Dr. Stebbings said that the grab samples don't vary much in comparison with most environmental measurements in epidemiologic studies. "The extreme range of the data makes an epidemiologic study of ra-

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don much easier than one of indoor or outdoor pollution, lead, insecticide levels, or anything comparable," he explained. The entire series of studies will take at least five years to complete, although some data should be available by the summer of 1988.

• *New Jersey:* A case-control study of lung cancer cases, diagnosed in 1982 and 1983 in New Jersey, includes 994 women with lung cancer and 995 controls. The study has documented information on smoking habits, occupation, diet, and residential history, said Janet Schoenberg, MPh, chief of the Cancer Epidemiology Program of the New Jersey State Department of Health. Short term (4-day) as well as long-term (1-year) measurements of radon are being recorded, and the initial data analysis will begin in the summer of 1987. Collection of the case-control data was funded by the National Cancer Institute, and follow-up collection of radon samples is being funded primarily by the State of New Jersey.

• *Sweden:* Methodologically similar to the New Jersey study, a survey of lung cancer admissions to three hospitals (two in Stockholm and one in Halsov), is being carried out by researchers at the National Institute of Environmental Medicine and the Karolinska Institute. "We are looking at 209 cases, 207 population controls matched for age, and 193 hospital controls," said Christer Svensson, MD, of the Department of Cancer Epidemiology at the Karolinska Institute.

Data collection began in September of 1983. In addition to radon exposure, the effects of smoking, passive smoking, and intake of vitamins A and C are being evaluated. Radon measurements in a sample of dwellings where cases or control subjects have lived were completed last spring. Although the project is mainly funded by The Swedish National Bank, the track etch detectors used were provided by the Radiation Epidemiology Branch of the US National Cancer Institute. A larger program, involving one-year radon measurements in approximately 1,500 homes, will begin this year.

Indoor radon from ground sources is a concern in Stockholm because the city is partly built on glacial eskers and granite, which emit the gas. One of the first case-1 control studies of lung cancer incidence and indoor radon exposure said Dr. Svensson, was published in Sweden in 1979 (*5*). A more recently published study of 292 female lung cancer cases and 584 matched population controls indicated that increased indoor radon daughter concentrations were etiologically important (*6*).

• *Canada:* The Bureau of Radiation and Medical Devices, of the Health and Welfare Department of Canada, is carrying out a study of 700 lung cancer cases and 700 controls in Winnipeg. The Cancer Institute in Manitoba is collecting the cases, interviewing, and measuring radon levels, said Roger Eaton, PhD, senior project officer. "The reason we chose Winnipeg is that, according to a survey done in the late 1970s and early 1980s, that city has the highest natural levels of radon, averaging approximately 1.4 pCi/l (51 Bq/m^3) from single grab sample measurements," said Dr. Eaton. The study has been under way for two years, and is expected to be completed by 1990.

Last month at the SNM 34th Annual Meeting in Toronto, Canada, a panel discussion, "Radiation in Perspective: Chernobyl, Radon, and Nuclear Medicine," was held in honor of Eugene L. Saenger, MD, of the University of Cincinnati, who received the 1987 SNM Nuclear Medicine Pioneer Award. Dr. Fabrikant, chairman of the BEIR IV Committee, presented an overview of radon risks.

"The present need to apply lung cancer risk projections from surveys of underground miners to estimate risk to the general population from indoor radon introduces numerous uncertainties and technical difficulties. The domestic environment has not yet been adequately characterized, and much more study at the epidemiologic and basic research levels is needed. Further research on dosimetric modeling is necessary to determine the comparability of risk per WLM in household environments as opposed to underground mines," said Dr. Fabrikant.

[The panel discussion, "Radiation Risk in Perspective: Chernobyl, Radon, and Nuclear Medicine," is available on cassette tape. For more information on audiovisuals from the 34th SNM Annual Meeting, held in Toronto, Canada, June 2–5, 1987, contact: SNM Audiovisuals, PO Box 10503, Chicago, IL 60610, (312)943-0450.]

Betsy Hanson
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