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When Pennsylvania Discovered Radon (December 1984)

[*The Pennsylvania Experience With Indoor Radon*](#)

by

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Pennsylvania Dept. of Environmental Resources (1986)

[*The Pennsylvania Radon Story*](#)

by

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Director, Bureau of Radiation Protection
Pennsylvania Dept. of Environmental Resources (1987)

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The Pennsylvania Radon Story

by

Thomas M. Gerusky
Director, Bureau of Radiation Protection
Pennsylvania Dept. of Environmental Resources (1987)

Abstract

In December 1984, the Pennsylvania Bureau of Radiation Protection found itself confronted with the discovery of a home in eastern Pennsylvania having the highest level of radon daughters ever reported. The Bureau responded with a massive radon monitoring, educational, and remediation effort. As of November, 1986, over 18,000 homes had been screened for radon daughters, of which approximately 59% were found to have levels in excess of the 0.020 Working Level guideline. Pennsylvania's response to the indoor radon problem is detailed in this article.

As with most State Radiation Control Programs, Pennsylvania recognized that naturally occurring radon gas was a potential indoor air pollution problem in geologic areas with elevated levels of uranium ore. It was also recognized that other states had already been working to resolve the problem for specific areas in their respective states. It was generally believed that the most significant problems were located in areas where man had enhanced the uranium environment, such as the Grand Junction area of Colorado where uranium mill tailings had been used for fill around newly constructed or remodeled buildings (1).

Elevated levels of radon were also reported from other areas of the country. Florida had a serious problem on phosphate lands; Montana had detected elevated levels in the Butte area, and Pennsylvania and other states had experienced elevated radon levels in the vicinity of uranium and radium extraction facilities (2). The U.S. Department of Energy had designated certain sites for decontamination and remedial action at facilities operated for the federal government during and after the Manhattan Project days (3).

In the late 70's, Pennsylvania Power and Light Company, a utility operating in central Pennsylvania, carried out a study involving radon measurements in homes of their employees to determine if weatherization programs were effective (4). Radon was selected because of the relative ease of measurement. To their surprise, elevated radon levels were found in some homes, but there appeared to be no correlation between radon levels and home construction or location. The data were reported to the Pennsylvania Bureau of Radiation Protection (Bureau), and plans were made to begin a pilot project to determine radon levels in other areas of the state. The March 1979 Three Mile Island accident caused a major change in Bureau priorities and the survey was placed on the back burner. Plans were again made in 1984 to begin a modest survey program in the 1985-86 fiscal year as outlined in the annual budget submitted to the Pennsylvania General Assembly by Governor Thornburgh.

We did not have to wait that long. In December 1984, the Bureau received a telephone call from the Health Physicist at the Limerick Nuclear Generating Station informing us that a construction worker at their still incomplete plant was setting off alarms when he attempted to enter the plant through portal radiation monitors. Since the plant was not yet generating fission products, health physicists from the utility and their consultant performed a radiation survey in the home of the individual and found very high levels of radon daughters throughout the structure. Radon daughter levels (concentration of decay products of radon in the uranium chain) ranged up to 13 Working Levels (WL) or 2600 pCi/l of radon gas.

Numerous resurveys verified those findings, and estimates of exposure and risk of lung cancer were attempted. A search of the literature on radon and radon daughter concentrations in residential structures made us aware that this was the highest level ever found in a private residence (5). The National Council on Radiation Protection and Measurements (NCRP) had issued two reports on radon and radon daughter exposures of the residents of the home (5). The dose equivalent rate to the bronchial epithelium of the lung from continuous exposure to radon daughter concentrations of 13 WL was calculated to 13 WL in one year is .13 or 13 chances out of 100.

A decision was made to officially recommend that the occupants vacate the residence, and a formal recommendation was made by a hand-carried letter signed by the Secretary of Pennsylvania Department of Environmental Resources. The Philadelphia Electric Company and Bechtel, Inc., the contractor employing the individual, assisted in providing living arrangements for the family until remedial action could be taken in the home.

Assuming this was not an isolated case, the Bureau designed a house-to-house campaign to evaluate radon levels in the immediate neighborhood. Unfortunately, there were and are no standards for exposure to radon or radon daughters for the general population. NCRP recommends an annual exposure guideline of 2 WL Months/yr, which corresponds to a continuous exposure guideline of 0.04 WL (5). Other guidelines have also been used. The Environmental Protection Agency (EPA), with assistance from the Centers for Disease Control (CDC), has recommended remedial action at 0.02 WL (5). The Pennsylvania Department of Health requested assistance from CDC in determining such guidance. One WLM per year or 0.02 WL continuous occupancy was received as guidance, with a sliding time scale for remedial action based upon levels detected. Table 1 was utilized as guidance to homeowners.

Table 1
Commonwealth of Pennsylvania
Recommended Action Guidelines
To Reduce Radon Daughter Exposure

OBJECTIVE: To reduce radon daughter exposure levels to .02 Working Levels (WL) or less, if possible, through corrective action.

Tier	If Your Home Measures*	Suggested Actions**	Time Frame For Action
I.	more than 5.0 WL	Residents should either promptly relocate or undertake temporary remedial action to lower levels as far below 5.0 WL as possible. Smoking in high areas discouraged.	Within 2-3 days
II.	1.0 to 5.0 WL	Residents should undertake temporary remedial action to lower levels as far below 1.0 WL as possible. Smoking in high areas discouraged.	Within 1 week
III.	0.5 to 1.0 WL	Residents should undertake temporary remedial action to lower levels as far below 0.5 WL as possible.	Within 2 weeks
IV.	0.1 to 0.5 WL	Residents should undertake temporary remedial action to lower levels as far below 0.1 WL as possible. Higher exposure levels require action to be taken in a shorter period of time.	3 week to 3 months
V.	0.02 to 0.1 WL	Residents should undertake temporary and/or permanent remedial action to lower levels below 0.02 WL. Higher exposure levels require action to be taken in a shorter period of time.	4 to 15 months

* Assumes continuous 24-hour exposure in living area.

** Home testing should be conducted at the end of the indicated time frame to determine if remedial action has reduced the radon daughter exposure levels below the indicated value. If remedial action has not been successful, residents should be aware of the risks associated with continuous exposure at the indicated levels.

The door-to-door survey campaign revealed additional homes with elevated levels, some in excess of 1 WL, but none as high as the first reported home. Air samples were taken in the basement of the home, or

the lowest possible living space, to perform screening on as many homes as possible. Alpha-track radon monitors were also placed in the home to determine average levels. Over 2600 homes were visited and levels in excess of 0.02 WL were found in approximately 50% of the cases (Table 2). Data obtained from the home surveys is confidential and will be released only with the homeowner's consent. Schools and other public buildings were also surveyed, with only a few found to be above 0.02 WL.

Table 2
Pennsylvania Department of Environmental Resources
Bureau of Radiation Protection

August 25, 1986
Results of Initial House-to-House Surveys
Track-Etch Data

No. of Homes Surveyed	2641	Percent	
- Above 1.0 WL	19	0.7	
- 0.500 to 0.999 WL	29	1.1	
- 0.100 to 0.499 WL	260	9.8	49.8%
- 0.050 to 0.099 WL	334	12.6	
- 0.021 to 0.049 WL	675	25.6	
- 0.010 to 0.020 WL	732	27.7	
- 0.000 to 0.009 WL	593	22.5	50.2%

The immediate area in question was located in Berks County in eastern Pennsylvania. Geologists have located a formation known as the Reading Prong which contains elevated levels of uranium and thorium. In the 1970's, the U.S. Department of Energy (DOE) performed an aerial radiation survey of the area in an attempt to locate potentially recoverable uranium resources. Pennsylvania geologists, under a grant from DOE, have performed a road survey and plotted environmental radiation levels on a map of the area. The Reading Prong extends from east of Reading through three counties to Easton and on into New Jersey, New York, and parts of New England.

We requested and obtained assistance from the EPA Office of Radiation Programs for additional equipment, for performing house-to-house surveys, and for laboratory assistance in evaluating radon levels in well water supplies. DOE supplied a helicopter to perform a detailed aerial gamma radiation survey of the initial township, and a monitoring van from their Oak Ridge National Laboratory in Oak Ridge, Tennessee to determine whether ground surveys could identify high radon houses. It was found that background radiation in the area was too high to distinguish a house with high concentrations from the background radiation levels. The aerial surveys were very helpful in determining areas where homes might have high radon concentrations, but the cost was too great for a massive survey.

Remedial techniques were not well understood and the literature was confusing. Pennsylvania hired a consultant from Colorado to perform detailed radon diagnostics in 25 homes, to provide potential remediation strategies for the homes, and to provide a generic document that could be used by homeowners across the Commonwealth to correct their radon problems.

A fact sheet on radon was prepared with the assistance of the Pennsylvania Department of Health's Environmental Health staff, and public meetings were held in the areas being surveyed in an effort to provide as much information to the public as possible. A Spanish version was prepared and a contract with an area Spanish Community organization was entered into to provide for public information for the Spanish speaking community in the Allentown-Bethlehem areas of the state.

A Bureau office was established in the vicinity of the survey area and personnel from other Bureau activities were reassigned from their regular duties to perform radon surveys. Over \$1 million was spent in the first six months of the program.

An additional \$1 million was placed in the budget for radon testing during fiscal 85-86, and 20 new positions were established to perform surveys. A toll-free radon hot-line was set up to answer questions from the public and to schedule survey visits.

EPA had established a research and development program on low-cost remediation techniques and diverted the program to the Reading Prong area where 18 houses were remediated in a demonstration project.

We requested additional assistance from EPA, realizing that other Reading Prong situations must exist in other areas throughout the U.S. Low-cost screening methods, protocols for measurements, training for staff, and remedial contractors, and a formal comparison procedure for different monitoring systems and techniques have been established by EPA.

Since the house-to-house survey program was very personnel-intensive and exceeded the staff time available, and since less than 30% of the homeowners in the area were requesting surveys, a new screening method was devised. The Reading Prong does not follow political or other boundaries, so the area of the prong was included in expanded boundaries which could be easily distinguished. Ads were placed in newspapers in the three-county area showing a map and a list of the townships included in the expanded coverage area. A free mail-order alpha-track monitor would be sent to any resident of the area who mailed the Bureau a coupon, which was included in the ads.

Approximately 25,000 requests were received, and monitors were mailed to over 21,000 households. The results obtained to date are listed in Table 3. Over 60% of the homes have screening values in excess of 0.02 WL.

Table 3
Pennsylvania Department of Environmental Resources
Bureau of Radiation Protection

November 24, 1986
Radon Daughter Screening Results
Alpha-Track Mail Program

No. of Homes Surveyed	15544	Percent	
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> 1.0 WL	83	0.5	
0.500 to 0.999 WL	136	0.9	
0.100 to 0.499 WL	1689	10.9	60.3%
0.050 to 0.099 WL	2492	16.0	
0.021 to 0.049 WL	4973	32.0	
0.010 to 0.020 WL	3799	24.4	
0.001 to 0.009 WL	2372	15.3	39.7%

Because the method is to screen potentially high homes, the monitors were to be placed in basements, the areas of the homes with the highest potential for radon accumulation. Those homeowners with screening levels between 0.02 and 0.1 WL are sent another alpha-track monitor to be placed in the living quarters for a year to determine annual average levels of exposure.

Those in excess of 0.1 WL are visited by our staff for more detailed evaluations and recommendations are made for remedial action. Charcoal canisters are now being used instead of the air sample method because of increased reliability of data.

Following the current campaign in the expanded Prong, additional screening studies will be carried out in Pennsylvania to determine if other clusters or extended areas of elevated radon do exist. Private monitoring firms have reported finding homes with high concentrations in areas outside the Prong, and Pennsylvania geologists are evaluating other areas.

For the 1986-87 fiscal year, \$1.3 million has been approved in the Department's budget for radon studies, and an additional \$1 million for a remedial action demonstration project was passed by the legislature. It is anticipated that over 100 homes will undergo remedial measures free of charge in an attempt to prepare a more detailed and lower cost remedial guide for the homeowner.

A low-interest loan program has also been established to assist homeowners in funding remedial actions in their residences. For schools and other public buildings, the department has hired a consultant to provide detailed plans for remediation. Very few public buildings have been found to have significant problems because of construction techniques and the requirements for a certain number of air changes per hour as standard practice.

Argonne National Laboratory, with funding provided by the U.S. Department of Energy, is conducting an epidemiological study of residents of the area to determine if the incidence of lung cancer in non-smoking females in the eastern 40% of Pennsylvania is related to their radon exposures. Present data are not precise enough to identify any such increase.

In summary,

1. Pennsylvania responded to the radon issue in the belief that it had public health responsibility and a moral obligation to assist as much as possible.
2. Pennsylvania has no legal authority to enter private residences without the consent of the homeowner, and no authority to require monitoring or take remedial action.
3. Pennsylvania has received technical and in-kind help from the federal agencies but no direct monetary support.
4. Pennsylvania believes the issue is so significant that a permanent program is being established in the Bureau of Radiation Protection to continue that screening, detailed evaluation, and follow-up of radon-infiltrated homes.
5. Pennsylvania believes the problem to be international in scope and strongly recommends that other states and federal agencies carry out screening and, where necessary, remedial action programs.

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This article is from the January/February 1987 issue of the *Journal of Environmental Health.*

THE PENNSYLVANIA EXPERIENCE WITH INDOOR RADON
Presented at:
ATOMIC INDUSTRIAL FORUM
CONFERENCE ON NUCLEAR INDUSTRY RADIATION ISSUES:
1986 AND BEYOND
by
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Bureau of Radiation Protection
Department of Environmental Resources
Commonwealth of Pennsylvania
October 8, 1986

Nothing is as difficult to deal with as the shattering of a closely held belief. In Health Physics, especially among the fission product crowd, natural radioactivity, including radon to some extent, had been a parenthetical issue. Results were expressed as (twice background), or air particulate analyses were

delayed (to allow for decay of short lived radon daughters). Radon was a nuisance. The management of fission product and by product problems consumed a large fraction of the nuclear talent in the nation. For some, however, things were about to change.

At mid-day December 19, 1984 during the Christmas lunch in the Department of Environmental Resources, Bureau of Radiation Protection, the Senior Health Physicist at Limerick Generating Station called with a message which shook old beliefs. He indicated that a contractor engineer at the site had been tripping the recently installed portal monitor on his way to meeting outside and at the end of shift. The facility had not yet achieved criticality. The contamination was radon daughters. The administrative burden to the station and the inconvenience to the engineer were noticeable. Earlier that week the engineer decided to use the portal monitor on the way to work. His surface contamination set off all the detectors (large, thin window gas flow proportional counters) in the array. He asked the utility to sample his house, since that had to be the problem. It was. Utility consultants found in excess of 10 Working Levels (WL) radon progeny activity in the air of the engineer's home. Based on our limited knowledge at the time, that sounded like a lot.

Since the problem was obviously not of nuclear power origins, the utility was interested in handing it off to the appropriate state agency, and rightfully so. A one day's grace was begged to allow us to become somewhat conversant in the issue. That night NCRP Report No. 77 and No. 78 were speed read. Using risk estimates and dose estimation factors in those documents, the maximum annual dose equivalent to lung epithelium was estimated to be to the order of 10,000 Rem with a lifetime risk of lung cancer over 10% per year of exposure.

The next day we contacted the engineer employed at Limerick to discuss the matter. He asked whether he should get his family out of the house. We could not argue against it. We arranged to visit the house on December 26. The family stayed with relatives in a neighboring state over the holiday.

On December 26 alpha track radon gas detectors were posted in the house, along with thermoluminescence dosimeters (TLD) for measuring gamma exposure. High volume air samples were collected on charcoal to establish the presence, if any, of thoron. (None was found.) Micro-R meter readings in the basement were in the range of 100 uR/hr. The gamma exposure rate was a combination of shine through the floor plus immersion in airborne gamma emitting radon progeny.

The passive detectors were retrieved on January 2, 1985. The radon gas concentrations ranged from 100 pCi/l (0.5 WL) in the garage, to 2700 pCi/l (13.5 WL) in the basement. An alpha track detector posted in the stand pipe of the septic system was in agreement with basement data. This tended to suggest that the problem indeed arose from the ground rather than building materials. TLD results from the basement extrapolated to over 900 mrad/year.

Soil samples were collected, along with a tap water sample. Soil radium concentrations ranged to 15 pCi/g. Water radon concentration was about 15,000 pCi/l. Radium was found in a sample of basement wall efflorescence.

On January 5, a letter was hand delivered to the family, strongly recommending their vacating the house. They did.

Meanwhile, officials of Colebrookdale Township was contacted to advise them of the situation, and to ask their cooperation in arranging home visits. With their help, we took measurements in the homes of immediate neighbors and several other homes in the township. Although several homes had moderate to

high radon concentrations, none were nearly as severe as the index house.

For those who believe that random sampling is adequate to assess indoor radon problems, note should be taken that one immediate neighboring house had a radon concentration of less than 2 pCi/l. This compared to 2700 pCi/l in the index house.

By now it is rather common knowledge that the region of concern is a physiographic province known as the Reading Prong. The province underlies parts of Pennsylvania, New Jersey, New York and Connecticut. In Pennsylvania the Prong begins in the hill just east of Reading and runs east-north easterly just south of Allentown, Bethlehem and Easton to the Delaware River. Outlying pieces of Prong are also located north of the Lehigh River in Allentown and Bethlehem, and north of Easton. It includes parts of Berks, Bucks, Lehigh and Northampton Counties. The areal extent is about 300 square miles with an estimated housing stock of 22,000 homes.

The Reading Prong had long been known to have enhanced abundance of uranium and thorium. In the mid-to-late 1970's, the Pennsylvania Geologic Survey (PGS) had done a carbene gamma survey in the Prong in an effort to locate uranium anomalies. This effort was a supplement to USDOE aerial surveys to locate uranium and estimate national reserves at a time of higher demand.

An informal plan to examine radiation hazards in the Prong was scheduled for the spring/summer of 1979. The concerns at the time were basically ambient gamma and ingestion pathways. Radon was alien. Events elsewhere overshadowed 1979 and several years thereafter.

By mid-January 1985, the Department of Environmental Resources went public on the issue by offering radon surveys at no cost to interested householders in Colebrookdale Township, Berks County.

In the interim, the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) were contacted to request technical assistance. EPA teams took measurements in several hundred homes. The Agency also provided laboratory support for well water analysis. DOE provided a helicopter survey for terrestrial gamma emitters for the immediate vicinity and van-borne gamma analyzer for surface land characterization.

At the outset of the project, the situation suffered from the lack of a widely accepted criterion for radon/radon progeny concentration in domestic air. Discussions with the Pennsylvania Department of Health, the Center for Disease Control, and EPA led to the selection of 0.02 WL radon progeny concentration which corresponds to 4 pCi/l radon gas concentration.

During the first phase of the project, which continued into the Fall of 1985, the survey effort consisted of taking a grab air sample in the basement for analysis using the modified Kusnetz method, the posting of alpha track detectors for one to three months, the collection of tap well water samples for radon if requested, and a micro-R survey. Results of the Kusnetz samples were telephoned back to the homeowner as soon as the results were available. Kusnetz, alpha track, and water results were provided in writing after receipt of alpha track data.

Homes with basement Kusnetz results over 0.1 WL underwent integrated radon progeny measurement for several days in normal living space. The instrument used was the EPA radon progeny integrated sampling unit (RPISU). This measurement estimated real exposure.

The house surveys also included gathering of information on house construction characteristics, and

demographic information such as number and age of occupants, smoking history, length of occupancy, and identity of previous owners.

By February 1985, a fact sheet was published. A table for estimating risk, and a tiered recommended schedule for lowering radon progeny exposure were produced. It was clear from the onset that remediation of homes would be the responsibility of the homeowner. Since we were aware of only two forms in North America with any experience in radon remediation, some creativity was in order. Radon remediation, then and now, was not something widely understood in the general contractor community.

The Department contracted with one of the available firms to characterize 25 selected houses for routes of radon entry, and to develop remedial designs for those houses. From this they developed a booklet of passive remedial designs. The designs for the individual houses were sent to the homeowners. The booklet was available for general distribution by early May 1985.

Beginning in January 1985, all school buildings in the Reading Prong in each Township were screened for radon as the project progressed. By late summer the program focused on all school buildings in the Prong, then, to all school buildings in the eligible area for mail order detectors. Eventually all school buildings (131) of any school district having any buildings in the Prong were surveyed. A total of 40 buildings had rooms over 0.02 WL.

To assist school districts where elevated radon concentrations were found, the Department contracted to have the problem building diagnosed and a menu of remedial options developed. The report of the diagnostics and remedial designs are provided to the subject school boards for their use.

Starting in the summer of 1985 the Department contracted with the Berks County Votek School to provide training to homeowners, contractors and building inspectors in the use of these remediation options.

In early 1985 the Department learned of EPA plans to demonstrate low cost semi-passive remedial designs. We requested their including homes in our project area: Eighteen homes were selected. Work began in the summer of 1985.

In April 1985 Philadelphia Electric Company took on the project of attempting to remediate the index house. This research project was multiphased. The first phase consisted of excavating the exterior basement walls to the footing and installing a radon-opaque membrane and new drain tile. The excavated volume was replaced in large part with washed gravel.

The second phase consisted of application of epoxy paint on an interior basement stub wall which had shown a high radon flux rate. The top of the stub wall was fitted with an accumulator to attempt to draw radon out of the concrete masonry unit cavities.

The third phase consisted of dressing floor cracks and the basement floor slab perimeter french drain, and filling with flowable silicone sealant.

These three phases combined brought the basement concentration down from over 10 WL to about 2 WL.

The fourth phase consisted of the removal of the slab on two levels, and the installation of a subslab ventilation system. Since the slab had no aggregate beneath it, at least a foot of bedrock had to be hammered out to make space for the diabase aggregate gas lines, the slotted drain tile network imbedded

therein, a sand cushion, radon opaque membranes and the new four inch slab.

Diabase was used in place of regular ground due to a perceived need to provide shielding from insitu uranium in the native rock. Samples of bedrock from beneath the floor contained 50 ppm uranium. The locally produced diabase contained 15% iron oxide, a condition which raises the shielding effectiveness of the fill due to an increase in the atomic number fill material. The drain tiles were connected to two vertical stacks extending up through the house to the roof. Wind turbines provide a slight negative pressure to the drain tile and aggregate gas lens to draw radon bearing soil gas.

To avoid future controversy regarding disposal of the old slab, excavated dirt and rock, all these materials were retained on the property, covered with topsoil and regraded.

The family returned to the house on July 3, 1985. Basement radon progeny concentrations stabilized at about 0.02 WL. The ambient gamma in the basement is at or below 20 Micro-R/hr.

As the survey project proceeded to the various townships, it began to emerge that the practice of individual house visits would require years to cover the entire Reading Prong. In addition, the participation rate was much less than one would expect, given the health risks involved. Participation rates ran from 12% to 33% of eligible homes. In an effort to increase coverage fast, a mail order campaign was organized for distribution of alpha track detectors in the Reading Prong.

Since the Prong completely ignored political boundaries and other cultural features, the Department had to expand the area eligible for mail order detectors to meet some recognizable boundary. A full page paid advertisement was placed in each of 5 regional newspapers in the Sunday edition of October 13, 1985 and again the following Wednesday. The ad was preceded by pair radio spot announcements during drive time at the end of the preceding week. The response was literally overwhelming with over 10,000 requests received the first week, of which 75% were really eligible. Several requests were received from New Jersey residents! To date about 23,000 detectors have been sent out for screening purposes.

Those homes where basement screening results ranged from 0.02 - 0.10 WL (4-20 pCi/l) were sent a second detector for finding annual exposure in normal living space. Homes where screening results exceeded 20 pCi/l are visited by a field team for further verification measurements, and information gathering.

In early October Governor Thornburgh announced the development of a 3,000,000 low interest loan program for home radon remediation. Administrative elements were developed and the program went public in late Spring 1986 with the mailing of over 8,000 loan information packages to all homes known to exceed 0.02 WL.

As 1985 came into its final days, the Department was advised of a house at 10 WL in the Prong north of Easton. A separate mailing was made to homes in that area to advise them of the local problem and to invite them to ask for detectors. A similar follow-up is underway for other neighborhoods where significantly elevated houses have been identified.

To date (September 15, 1986) data have been collected from over 17,000 homes (table 1). The criterion of 0.02 WL was exceeded in about 59% of the homes. One Working Level was equalled or exceeded in 101 homes.

For 1986, the "big thing" appears to be remediation. EPA developed a three day course in structure

diagnosis, remedial techniques, and supporting measurements for training government and private sector. The course has been presented several times in Pennsylvania and other Prong states.

In June 1986 Act 62 was passed by the General Assembly and signed by Governor Thornburgh. The legislation provided \$1,000,000 for the Department to use to research and demonstrate remedial actions.

In addition EPA will be diagnosing 80 more houses and recommending remediation methods to the homeowners. Most if not all of these homes will be remediated using Act 62 money. The Act 62 money is expected to treat a total of 100 to 200 homes. The Department is contracting with an architect/engineering firm to manage the actual construction work.

By late 1987, the radon community may have a much better understanding of remedial techniques.

Coming events in the Pennsylvania radon effort include surveys in homes in other areas suspected of harboring uranium anomalies. The Pennsylvania Geologic Survey is doing carbene gamma surveys in other areas underlain by precambrian granitic gneisses and dark marine shales.

Several epidemiological studies are under consideration or underway. One, which was conceived before the index house was found, is a case matched retrospective study of lung cancer in nonsmoking females in the eastern 40% of Pennsylvania. The study is being conducted by Argonne National Laboratory using DOE money. The expected time to completion is five to seven years.

The general area of epidemiology of lung cancer due to domestic radon exposure needs work. The only epidemiological basis is the uranium miners and related occupations. Uncertainties exist as to the applicability of their risks to population-at-large. Perhaps the one way to address that issue is by establishing a registry for individuals with a high exposure history. Attempts to correlate incidence of disease for various areas using vital statistics data are usually flawed since the published data reflects municipality where the diagnosis or death occurred. This is not frequently the place where the risk accrued, given our current mobile society. Also given the comparatively large "background" of lung cancer due to smoking and other agents, it is difficult to detect a difference in rate of incidence.

Nevertheless, given our current understanding of radon progeny exposure risks from NCRP Report No. 77, one rapidly comes to the conclusion that domestic exposure may be the largest radiation related source of mortality we have. Consider that continuous exposure to 0.02 WL for 40-45 years yields a 1% risk of lung cancer. If the lifetime risk accrued per year of exposure is 2×10^{-4} at 0.02 WL, one can do all sorts of estimates. Assume 10,000 homes, each within 3 occupants, with a concentration of 0.02 WL for only 10 years, with a 50% occupation factor. This yields 30 fatalities, total. Assume 100 houses at 1.0 WL, with all other variables held constant, with the foregoing, and the yield is 15 cases total.

Some conversions are offered for the readers use and abuse (Source: NCRP Report No. 77):

- 4 pCi Rn-222/l air yields 0.02 WL.
- 0.02 WL continuous exposure (8760 hours, 100% occupancy) for 1 year yields 1.0 WL - month. 1.0 WL - month yields 0.7 Rad absorbed dose.
- " " yields 14 Rem at QF - 20.
- " " yields an annual risk of 2×10^{-4} .
- " " per year over 45 years yields a lifetime risk of 9×10^{-3} (1%).

Example:

Suppose a family of 4 spends one-third of its time in a room with a concentration of 80 pCi/l (0.4 WL) for 20 years. The individual lifetime risk from that exposure is 2.6%. The combined family risk is 10.6% that someone is committed to lung cancer. The individual total exposure is 132 WL - months. The individual absorbed dose is 92.4 Rad, and, dose equivalent is 1294 Rem to lung epithelium.

After about two years of total immersion in the radon issue, a few lessons should have been learned. Several are offered below:

1. Indoor radon/radon progeny concentration dependencies:

- Underlying geology (U content)
- Soil porosity and permeability
- Prevailing weather
- Barometric pressure changes
- Snow cap (or other lid)
- Wind speed and direction
- Chimney effect
- Ventilation rate
- Occupant behavior
- Season of the year
- House idiosyncrasies
- Heat distribution method
- Domestic water Rn content
- Time of day, day of the week
- Tidal forces

2. False beliefs held by radon novices:

- It's got to be the building materials!
- It's got to be the house style. . .

colonials > split levels > cape cods

> baronical estates!

- Poured concrete foundation walls are always radon proof.
- New houses are worse than old homes.

3. If you think you don't have a radon problem, you haven't looked hard enough.

4. Nowhere is it written that radon/radon progeny data have to make sense.
5. When radon/radon progeny data begins to make sense, you have probably settled on a false conclusion.
6. Indoor air usually runs at about 50% equilibrium; 100 pCi/l Rn yields 0.5 WL. The rest of the Rn progeny have to go somewhere. This balance is the unattached fraction.
7. The unattached fraction goes everywhere; the carpet, the dog's fur, your clothing, your lung epithelium, your survey meter detector surface.

The net effect to the Bureau of Radiation Protection has been profound. During the first 6 months of 1985 the radon project was handled by existing staff and a contracted community relations consultant. A field office was opened in January 1985 in Gilbertsville. Extra costs in that period were \$1 million. For fiscal years 85/86 and 86/87 the budget each year has been \$1.3 million. A total of 21 new positions were added in fiscal 85/86. Act 62 provided another \$1 million for remedial research and demonstration.

TABLE 1
PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF RADIATION PROTECTION
SEPTEMBER 15, 1986
COMBINED SCREENING DATA
INITIAL AND MAIL ALPHA-TRACK RESULTS

Number of Homes Surveyed	17063	Percent	
Above 1.0 WL	101	0.6	
0.500 to 0.999 WL	163	1.0	
0.100 to 0.499 WL	1851	10.8	59.1%
0.050 to 0.099 WL	2655	15.6	
0.021 to 0.049 WL	5312	31.1	
0.010 to 0.020 WL	4223	24.7	
0.000 to 0.009 WL:	2758	16.2	40.9%

References

NCRP Report No. 77 - Exposures from the Uranium Series with Emphasis on Radon and Its Daughters.

NCRP Report No. 78 - Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States.

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