United States Environmental Protection Agency | Office of Research and Development | Air and Energy Engineering Research Laboratory Research Triangle Park, NC 27711

EPA/600/9-91/005 March 1991

EPA Radon Mitigation Research Update

Introduction

The Radon Mitigation Research Update is the second in a series of research summaries intended to provide recent information about EPA's radon mitigation research activities by the Air and Energy Engineering Research Laboratory (AEERL) and to compile a listing of recent Radon Mitigation Branch (RMB) research findings.

AEERL plans to publish future updates approximately two times a year. If you would like more information about specific research activities or programs, you may contact the appropriate RMB project officer at MD-54, U.S. EPA, AEERL, Research Triangle Park, NC 27711, or at the number listed below.

RMB Contacts

Mike Osborne, Branch Chief
(919) 541-4113
- EPA radon mitigation research and development program

A.B. "Chick" Craig
(919) 541-2824
- Senior Physical Scientist - Radon

Tim Dyess
(919) 541-2802
- Radon resistant new construction

Bruce Harris
(919) 541-7807
- Radon diagnostics and measurement technology

Bruce Henschel
(919) 541-4112
- Radon mitigation in existing houses

Kelly Leovic
(919) 541-7717
- Radon mitigation in schools

Ron Mosley
(919) 541-7865
- Radon data analysis

John Ruppersberger
(919) 541-2432
- Radon barriers and block permeability

David Sanchez
(919) 541-2979
- Mechanisms of radon entry and Florida Radon Research Program

Project Highlights

Indoor Radon Research Program—Strategic Plan

AEERL first embarked on an aggressive radon mitigation development and demonstration research program in 1984. Since that time, research has evolved from a program which focused on demonstrating mitigation techniques in houses with highly elevated radon levels, to a multi-faceted research, development, and demonstration program concerned with reducing radon to near-ambient levels (less than 1 pCi/L) in existing houses, new houses, and schools across the country.

This expanded effort responds to EPA's public health mission and the 1988 Indoor Radon Abatement Act's mandate to reduce radon-related health risk by reducing indoor radon to near-ambient levels.

To meet the demands of this expanded effort, AEERL has recently developed a 3-year Strategic Plan for the Indoor Radon Research Program that integrates the activities of five otherwise separate program areas—1) innovative and supporting technology, 2) existing attached and unattached houses, 3) new houses (including pollution prevention), 4) schools, and 5) technology transfer—into one comprehensive research effort.

An increased emphasis has been placed on innovative/supporting research in an effort to accelerate improvements in technology, lower the cost of technology, and facilitate the delivery of this technology to a larger and broader audience.

The Indoor Radon Research Program has five areas of major emphasis:

1) developing new and improved radon reduction methods through a better understanding of fundamentals,
2) de-emphasizing the demonstration of currently available radon mitigation technology in existing and new houses,
3) increasing the emphasis on mitigation system durability assessments and operating cost analyses,
4) continuing to identify, develop, and demonstrate radon mitigation options for schools and non-residential child care facilities, and
5) supplying a greater variety of audience-specific technology transfer products.

Utilizing this integrated approach, concepts developed in the Innovative and Support Technology area will be demonstrated in existing houses, new houses, and/or schools and other large buildings. Products resulting from each of these efforts will then be incorporated into technical guidance documents.

Printed on Recycled Paper

Florida Radon Research Program

RMB has coordinated and completed the delivery of recommendations and draft technical support documents to the Florida Department of Community Affairs for Standards for Radon-resistant Construction and Mitigation. The results of this effort will be published in 18 reports covering recommendations for 1) improved floor barriers, 2) subslab depressurization systems, 3) HVAC specifications, 4) fill material specifications, and 5) performance criteria. Data gathered by the Florida Radon Research Program is available through a central Geographic Information System (GIS) data base maintained by the Geoplan Center of the University of Florida.

Program and project planning for continuation of the EPA/Florida interagency research agreement has also begun. These plans include the initiation of a 2-year research effort to enhance the technical basis for the five task areas listed above, and to begin work on the development of a radon potential mapping basis for application of construction and mitigation standards. Work in all task areas will be undertaken in unoccupied research houses with development verified in newly constructed houses. Problem assessment and building characterization studies for large buildings will start in FY 91. (For additional information on this program contact D. Sanchez, Project Officer.)

Measurements In Previously Mitigated Houses

RMB is conducting measurements in previously mitigated (18 months or longer) test houses in an effort to establish the long-term effectiveness and durability of various mitigation systems.

Researchers have placed 6-month Alpha Track Detectors (ATDs) in a number of basement and slab-on-grade houses, mitigated by EPA or EPA contractors, to gather data on post-mitigation radon levels. Plans are under way to initiate similar activities in a large number of houses mitigated by private sector companies. The results of this study will allow RMB researchers to identify radon mitigation systems/strategies that are not effectively maintaining indoor radon levels below 4 pCi/L. Study findings will also help identify mitigation systems/strategies which show the greatest potential for reducing indoor radon levels to near-ambient levels.

Follow-up research will focus on identifying equipment and installation problems as well as house and soil characteristics which may have contributed to system failure. Research findings will be made available through AEERL publications and in future issues of *Radon Mitigation Research Update*. (For additional information contact B. Harris, Project Officer.)

Update of Technical Manuals

AEERL is currently updating a number of EPA technical guidance manuals to better assist in the dissemination of the most timely and accurate radon reduction research information. These updated manuals are scheduled for release later this year and include Radon Reduction for Detached Houses (Technical Manual), and Radon-Resistant Construction Techniques for New Residential Construction (Technical Guidance).

New Technical Manual

AEERL will also publish the first edition of EPA's Radon-Resistant New School Construction Manual. This new manual will be based largely on RMB's recent experience in existing schools and previous experience with radon-resistant new house construction techniques. It will provide the most up-to-date information available on the design of radon-resistant/easy-to-mitigate new school buildings.

1991 International Symposium on Radon and Radon Reduction Technology

Final plans are being made for the 1991 International Symposium on Radon and Radon Reduction Technology "A New Decade of Progress" to be held April 2-5 at the Adam's Mark Hotel in Philadelphia, PA. EPA will co-sponsor the event with the Conference of Radiation Control Program Directors (CRCPD). This is the third such conference to serve as a forum for the exchange of technical information.

The program includes 77 oral and 52 poster presentations in addition to 13 invited papers.

Over 600 representatives from radon mitigation companies, local, state, and federal governments, equipment manufacturers, academia, and research and development firms are expected to attend. The following agenda provides a summary of the conference's four session days:

Tuesday, April 2

Session I: Government Programs and Policies Relating to Radon

Session II: Radon-Related Health Studies

Poster Session: All Posters Relating to Sessions I, II, and III

Wednesday, April 3

Session III: Measurement Methods

Session IV: Radon Reduction Methods

Session V: Radon Entry Dynamics

Session VI: Radon Surveys

Poster Session: All Posters Relating to Sessions IV, V, VI, and VII

Thursday, April 4

Session VII: State Programs and Policies Relating to Radon

Session VIII: Radon Prevention in New Construction

Session IX: Radon Occurrence in the Natural Environment

Poster Session: All Posters Relating to Sessions VIII, IX, and X

Friday, April 5

Session X: Radon in Schools and Large Buildings

If you would like more information about the symposium, please contact Pat Heightchew, CRCPD, Inc., 205 Capital Avenue, Frankfort, KY 40601, (502) 227-4543. On-site registration will be available from 4 to 9 p.m. Monday, April 1, and from 7 a.m. to 5 p.m. Tuesday through Thursday.

AEERL Papers

This section lists and briefly describes the 18 RMB oral papers and poster papers which will be presented at the 1991 International Symposium. RMB Project Officers and lead authors are listed for each paper. For additional information on these research activities, please refer to the symposium pre-prints (available with symposium registration) or contact the appropriate RMB Project Officer listed on page 1.

Measurement Methods

Predicting Long-term Indoor Radon Levels from Short-term Measurements: Evaluation of a Method Involving Temperature Correction; R.B. Mosley, Project Officer, and T.A. Reddy. Oral Paper

Daily averages of year-long continuous radon measurements in three houses were used to present a method for temperature-correcting single short-term measurements of indoor radon in order to predict long-term averages. The thermal stack effect was demonstrated to have the most important single influence on radon concentrations. The method was found to reduce the uncertainty in estimated annual averages of radon concentrations significantly in one house, moderately in the second, and marginally in the third.

Correlation Between Short-term and Long-term Indoor Radon Concentrations in Florida Houses; D.C. Sanchez, Project Officer, and S.E. McDonough. Poster Paper

Eighty study homes, representative of typical Florida housing construction, with indoor radon concentrations in the 2-20 pCi/L range, are being simultaneously monitored using long-term and short-term monitors.

Data have been analyzed to isolate systematic seasonal variations and to derive confidence limits for predicted long-term (annual) averages from single or multiple short-term measurements. Thresholds have been determined below which a single short-term measurement can provide specific confidence that the long-term average radon level does not exceed 4 pCi/L. These results have been incorporated into Florida's draft building standards.

Soil Gas Measurement Technologies; D.C. Sanchez, Project Officer, and H.E. Rector. Poster Paper

This paper discusses soil-based radon and radium measurement technologies capable of providing useful information for evaluating land radon potentials. Findings indicate that, while the use of soil gas measurements to estimate radon potentials is still evolving, both radium- and soil-gas-based measurements can help identify land areas warranting special attention and consideration for radon-resistant construction.

Radon Reduction Methods

Causes of Elevated Post-mitigation Radon Concentrations in Basement Houses Having Extremely High Pre-mitigation Values; D.B. Henschel, Project Officer, and A.G. Scott. Oral Paper

Forty Pennsylvania basement houses with 1985-87 pre-mitigation radon levels in the 50 to 600 pCi/L range were reevaluated in 1989-90. The primary single cause of residual (post-mitigation) elevated radon levels in houses using active soil depressurization (ASD) was found to be reentrainment of high-radon fan exhaust. In houses using block wall depressurization systems, inadequate sub-slab depressurization appeared to be the major cause of problems. For other than ASD systems, inherent limitations within the systems are commonly the primary single cause of residual levels. Airborne radon resulting from radon in well water was an important secondary contributor in some houses.

Natural Basement Ventilation as a Radon Mitigation Technique; R.B. Mosley, Project Officer, and A. Cavallo. Oral Paper

The effectiveness of natural ventilation in reducing indoor radon levels was studied in two basement houses. The study found that a factor of two increase in the ventilation rate (opening basement windows) corresponded to as much as a factor of eight reduction in radon concentration. The researchers found a corresponding, but much smaller, decrease in the pressure differentials (radon driving forces) across the basement slabs.

Control Of Radon Releases in Indoor Commercial Water Treatment; B. Harris, Project Officer, and A.B. Craig. Poster Paper

Municipal treatment facilities, industrial process facilities, and other water treatment facilities may be at risk for high indoor radon levels. Water laden with relatively low levels of radon (400 to 600 pCi/L), when used in high volume commercial operations, may release enough radon to result in indoor levels in excess of 100 to 300 pCi/L in treatment rooms and adjoining offices.

Elevated radon levels identified in the Fish and Wildlife Service's National Fish Hatcheries were controlled by vacuum-stripping the incoming water and exhausting the radon outdoors. Hooding and exhausting air from immediately around discharge points also proved to be successful in reducing indoor levels.

Radon Mitigation Failure Modes; D.B. Harris, Project Officer, and W.M. Yeager. Poster Paper

Residential mitigation systems fail for a variety of reasons and some failures may not be immediately recognized by residents. This study identified three primary failure categories (design flaws, component problems, and occupant activities) and reviewed examples of failure modes in each category. Results indicate that some failures could be avoided if mitigators would design systems to minimize failures, install system monitors, and instruct homeowners on continued system maintenance.

Radon Entry Dynamics

Radon Entry into Dwellings Through Concrete Floors; D.C. Sanchez, Project Officer, and K.K. Nielson. Oral Paper

Porosities, radon diffusion coefficients, and air permeability coefficients were measured for typical Florida slab-on-grade housing cement mixes. Findings suggest that radon diffusion through an intact slab may account for indoor radon concentrations of 2 pCi/L if greater than 3,000 pCi/L exists in the surrounding soils. Radium concentrations of 5 pCi/g in the concrete similarly may account for more than 1 pCi/L of indoor radon. Diffusion measurements also exhibited a correlation with the water/cement ratio of the concretes.

Model Calculations of the Interaction of a Soil Depressurization System with the Radon Entry Process; R.B. Mosley, Project Officer. Poster Paper

This study uses a simplified analytical model of radon transport and entry into houses to estimate the influence of a mitigation system on the entry process. Modifications of the diffusive flux and the entry rate into the building by the action of the mitigation system are estimated in order to determine the total effect on emission of radon to the atmosphere.

A Modeling Examination Of Parameters Affecting Radon and Soil Gas Entry into Florida-style Slab-on-grade Houses; D.C. Sanchez, Project Officer, and R.G. Sextro. Poster Paper

The influence of soil, backfill, and construction characteristics on radon and soil gas entry is examined using a two-dimensional finite difference model employing cylindrical symmetry. At a constant building depressurization, steady state pressure, flow, and radon concentration fields were predicted. The model predicts that changes in backfill permeability will have significant effects on radon entry, while changes in block wall permeability are somewhat offset by increased flow and entry through other structural gaps.

Soil Gas and Radon Entry Potentials for Slab-On-Grade Houses; D.B. Henschel, Project Officer, and B.H. Turk. Poster Paper

A simple model is used to address the importance of subslab communications testing, including measurements of radon concentrations and soil gas flows through slab test holes, in determining the number and location of active subslab depressurization (ASD) suction holes. Findings suggest that pipes for ASD systems should be located along the perimeter of slabs and only at areas of relatively high radon entry potentials. The model also suggests that three or fewer properly placed suction points will often reduce indoor radon levels to below 2 pCi/L, even in problem houses.

Radon Prevention In New Construction

Building Radon Mitigation Into Inaccessible Crawlspace New Residential Construction; B. Harris and A.B. Craig, Project Officers, and J. Haynes. Oral Paper

Single, duplex, and quadruplex buildings were constructed utilizing a below-grade wood floor construction over an inaccessible crawl space due to highly expansive soils. Initial studies demonstrated the need for complete sealing of the floor system until a negative pressure could be maintained under each corner of the floor (at least 2.5 Pa).

Early measurements indicated radon levels of about 100 pCi/L in the unmitigated crawl space. Tests in the first buildings completed showed all units below 2.5 pCi/L except for one unit where the depressurization fan had been turned off. This unit measured 16 pCi/L and dropped to below 2.5 pCi/L when the fan was activated.

The Effect of Subslab Aggregate Size on Pressure Field Extension; A.B. Craig, Project Officer, and K. Gadsby. Oral Paper

The effects of particle size and particle size distribution on sub-slab pressure field extension (PFE) were evaluated using laboratory tests simulating conditions existing under slabs. Findings indicate that PFE is proportional to the average stone size (the smaller the stone size, the less the PFE), the stone size distribution (the narrower the stone size distribution, the greater the void volume and hence the PFE), and the shape of the stone (the smoother the shape of the stone, the lower the void volume and hence the PFE).

Preliminary Results Of HVAC System Modifications To Control Indoor Radon Concentrations; T.M. Dyess, Project Officer, and T.M. Brennan. Poster Paper

Preliminary testing in one energy-efficient house indicates that residential forced-air furnaces can be used to pressurize basements and prevent radon entry. By adding a supply air duct in the basement and modifying the HVAC unit to run continuously on low speed, 300 cfm of air was supplied to the basement maintaining +4 Pa relative to outdoors. The average radon levels dropped from 14.3 to 1.2 pCi/L. Further research will analyze the economic impact of these modifications and determine their viability as a low cost alternative to sub-slab depressurization in new construction.

Radon In Schools

HVAC System Complications and Controls for Radon Reduction in School Buildings; K.W. Leovic, Project Officer. Oral Paper

Initial data collected in four schools in Colorado, Maryland, Virginia, and Washington State confirm that, when outdoor air supply is increased using HVAC systems (forced air or unit ventilator), radon levels can be reduced. Depending on HVAC system design and initial radon levels, this approach may or may not be able to reduce levels to below 4 pCi/L. Table 1 illustrates reductions achieved by pressurization of classrooms (using existing HVAC systems) in one Washington State school.

Note that the classroom-to-hall doors had to be kept closed for the unit ventilators to reduce average levels to below 4 pCi/L, although radon spikes (as high as 25 pCi/L) still occurred.

Table 1. Average Radon Levels In Washington School During One Week

Location	Normal Operation: Average Radon pCi/L	(max)	Time Door Closed (%)	Test Operation: Average Radon pCi/L	(max)	Time Door Closed (%)	Subslab Radon Sniff, August 90 pCi/L
Room 139	2.6	(27)	97	1.2	(17)	76	400
Room 140	5.3	(29)	92	3.2	(7)	74	500
Room 141	4.8	(32)	88	2.1	(25)	75	700
Average	4.2	(29)	92	2.2	(16)	75	533

Research over the next year will be focused on determining optimal HVAC system operations and limitations of pressurization. Long-term research will include a comparison of HVAC modification and active subslab depressurization in the same schools.

Design of Radon-Resistant and Easy-To-Mitigate New School Buildings; A.B. Craig, Project Officer, and K.W. Leovic. Oral Paper

Recent experience in existing schools, new house construction, and limited experience in new school construction indicates that radon resistant features can and should be incorporated into new school buildings in high risk areas. Radon-resistant features work by reducing the potential for radon (soil gas) entry and facilitating cost effective post-construction mitigation. Pre-construction features include: designing, installing, and operating the HVAC system to pressurize the building providing adequate makeup air for building exhausts; laying down a minimum of 4 in. of clean, coarse subslab aggregate; limiting subslab barriers to air movement; and roughing in subslab depressurization points.

Design and Application of Active Soil Depressurization Systems in School Buildings; K.W. Leovic, Project Officer. Poster Paper

Recent research on active subslab depressurization (ASD) systems in two Kentucky and two Maine schools indicates that: 1) schools with low permeability material (i.e., sand) under the slab may require higher suction fans to adequately depressurize the subslab area; 2) utility tunnel depressurization may be an effective and relatively inexpensive technique if the tunnels are not too leaky and do not contain asbestos; 3) ASD systems are typically preferred to passive systems in existing schools to maximize radon reductions; and 4) subslab pressure field extension (based on measurements conducted in one school) is greater when suction is applied to an interior point rather than from the building exterior.

A Comparison of Radon Mitigation Options for Crawlspace School Buildings; K.W. Leovic, Project Officer, B.E. Pyle. Poster Paper

Research in one Tennessee school constructed over a crawl space indicates that sub-membrane depressurization is the most effective technology for reducing radon levels in both the classrooms and the crawl space. Crawl space depressurization was effective in reducing levels in the classrooms but increased levels in the crawl space by a factor of two to three. Both pressurization and natural ventilation of the crawl space were found to be less effective technologies than sub-membrane depressurization or crawl space depressurization.

RMB Papers and Reports Since Last Update

Reports Since Last Update:

"Testing of Indoor Radon Reduction Techniques in Central Ohio Houses: Phase 2 (Winter 1988-89)," Findlay, W.O., A. Robertson, and A.G. Scott, submitted to EPA by Acres International Corp., EPA-600/8-90-050, May 1990 (NTIS No. PB90-222704).*

"Testing of Indoor Radon Reduction Techniques in 19 Maryland Houses," Gilroy, D.G., and W.M. Kaschak, submitted to EPA by CDM Federal Programs Corp., EPA-600/8-90-056, June 1990 (NTIS No. PB90-244393).

"Radon Mitigation Studies: Nashville Demonstration," Pyle, B.E., and A.D. Williamson, submitted to EPA by Southern Research Institute, EPA-600/8-90-061, July 1990 (NTIS No. PB90-257791).

"Interim Radon-Resistant Construction Guidelines for Use in Florida—1989," Pugh, T.D., submitted to EPA by Florida A&M University, EPA-600/8-90-062, August 1990 (NTIS No. PB90-265349).

"Engineering Design Criteria for Sub-slab Depressurization Systems in Low-permeability Soils," Fowler, C.S., et al., submitted to EPA by Southern Research Institute, EPA-600/8-90-063, August 1990 (NTIS No. PB90-257767).

"Investigation of Radon Entry and Effectiveness of Mitigation Measures in Seven Houses in New Jersey," Dudney, C.S., et al., submitted to EPA by DOE/Oak Ridge National Laboratory, EPA-600/7-90-016, August 1990 (NTIS No. DE89016676).

"Identification of Candidate Houses for the North Florida Portion of the Florida Radon Mitigation Project," Roessler, G.S., et al., submitted to EPA by University of Florida, EPA-600/8-90-070, September 1990 (NTIS No. PB90-274077).

"Summary of EPA's Radon Reduction Research in Schools During 1989-90," Leovic, K.W., prepared in-house by EPA, EPA-600/8-90-072, October 1990 (NTIS No. PB91-102038).

"Testing of Indoor Radon Reduction Techniques in Basement Houses Having Adjoining Wings," Messing, M., submitted to EPA by Infiltec, EPA-600/8-90-076, November 1990 (NTIS No. PB91-125831).

"Follow-Up Annual Alpha-Track Monitoring in 40 Eastern Pennsylvania Houses with Indoor Radon Reduction Systems (December 1988-December 1989)," Scott, A.G., and A. Robertson, submitted to EPA by American ATCON, EPA-600/8-90-081, November 1990 (NTIS No. PB91-127779).

Symposia Presentations:

"Building HVAC/Foundation Diagnostics for Radon Mitigation in Schools: Part 2," Leovic, K.W., D. B. Harris, and A. B. Craig, presented at Indoor Air 1990, Toronto, Canada, August 1990.

"Planning for Quality in Radon Mitigation," Ford, J. S., and B. Harris, presented at Indoor Air 1990, Toronto, Canada, August 1990.

"Radon Diagnostics for Schools," Leovic, K.W., A. B. Craig, and D. B. Harris, presented at 83rd Annual AWMA Meeting, Pittsburgh, PA, June 24-29, 1990.

---

* All reports with NTIS members are available (prepaid) from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (phone 703/487-4650).

EPA Regional Offices

Region 1
(CT, ME, MA, NH, RI, VT)
JFK Federal Building
Boston, MA 02203
(617) 565-4502

Region 2
(NJ, NY)
26 Federal Plaza
New York, NY 10278
(212) 264-4418

Region 3
(DE, DC, MD, PA, VA, WV)
841 Chestnut Building
Philadelphia, PA 19107
(215) 597-8320

Region 4
(AL, FL, GA, KY, MS, NC, SC, TN)
345 Courtland St. N.E.
Atlanta, GA 30365
(404) 347-3907

Region 5
(IL, IN, MI, MN, OH, WI)
230 South Dearborn St.
Chicago, IL 60604
From IN, MI, OH, MN, and WI
(800) 621-8431
From IL
(800) 572-2515

Region 6
(AR, LA, NM, OK, TX)
1445 Ross Avenue
Dallas, TX 75202
(214) 655-7223

Region 7
(IA, KS, MO, NE)
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7020

Region 8
(CO, MT, ND, SD, UT, WY)
999 18th Street
Denver Place, Suite 500
Denver, CO 80202-2405
(303) 293-1709

Region 9
(AZ, CA, HI, NV)
75 Hawthorne
San Francisco, CA 94105
(415) 744-1045

Region 10
(AK, ID, OR, WA)
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-7660

EPA Headquarters
401 M Street S.W.
Washington, D.C. 20460
(202) 475-9605

Radon Hotline Number
1 (800) SOS-RADON

Response Form

AEERL welcomes your comments and suggestions regarding its programs and reports. To forward your remarks or to be included on our mailing list for future publications, please complete the following information and return it to: Kelly Leovic, MD-54, U.S. EPA, AEERL, Research Triangle Park, NC 27711.

Name______________________________

Business/Profession______________________________

Mailing Address______________________________

City____________ State________ ZIP________

Type of Business/Profession______________________________

❑ I would like to be included on AEERL mailing list

Comments______________________________

____

____

____

____

____

____

United States
Environmental Protection
Agency

Air and Energy Engineering
Research Laboratory MD-54
Research Triangle Park, NC 27711

FIRST CLASS
POSTAGE & FEES PAID
EPA PERMIT NO. G-35

Official Business
Penalty for Private Use $300

EPA/600/9-91/005

Library