#5651

Indoor Air Quality Update

A Guide to the Practical Control of Indoor Air Problems, from **Cutter Information Corp.**

37 Broadway, Arlington, MA 02174-5539 U.S.A. (617) 648-8700 TLX: 650 100 9891 FAX: (617) 648-8707

The 1991 International Symposium on Radon and Radon Reduction Technology

Volume II: Radon-Related Health Studies

100% recycled paper

The 1991 International Symposium on Radon and Radon Reduction Technology

Volume II
Radon-Related Health Studies

Opening Presentation

Comparative Dosimetry of Radon in Mines and Homes: An Overview of the NAS Report
Jonathon M. Samet, University of New Mexico

Session II: Radon-Related Health Studies

Lung Cancer in Rats Exposed to Radon/Radon Progeny
F.T. Cross and G.E. Dagle, Pacific Northwest Laboratory

Startling Radon Risk Comparisons
JoAnne D. Martin, DMA-RADTECH, Inc.

Estimating Radon Levels from Polonium-210 in Glass
H. Vanmarcke, Nuclear Research Center, Belgium; J. Cornelis, C. Landsheere, and A. Poffijn, State University of Gent, Belgium

Expanded and Upgraded Tests of the Linear-No Threshold Theory for Radon-Induced Lung Cancer
Bernard L. Cohen, University of Pittsburgh

American Lung Association's Radon Public Information Program — Panel
Leyla Erk McCurdy, American Lung Association

Developing a Community Radon Outreach Program: A Model for Statewide Implementation — Panel
M. Jeana Phelps, Kentucky Cabinet for Human Resources

Occupational Safety During Radon Mitigation: Field Experience and Survey Monitoring Results — Posters
Jean-Claude F. Dehmel, S. Cohen & Associates; Peter Nowlan, R.F. Simon Company; Eugene Fisher, U.S. EPA, Office of Radiation Programs

Following is the complete table of contents for the *1991 International Symposium on Radon and Radon Reduction Technology*. Each session is available as a separate volume from Cutter Information Corp. The cost per volume is $35 ($40 outside the US); or $25 ($30 outside the US) for subscribers to the ***Indoor Air Quality Update***™ or the ***Energy Design Update***® newsletters (ISSN 1040-5313 and ISSN 0741-3629, respectively).

To order additional volumes, call Kara Lovering at (617) 648-5125, or Fax: (617) 648-8707.

Or mail request to:
Cutter Information Corp.
37 Broadway
Arlington, MA 02174-5539, USA

The 1991 International Symposium on Radon and Radon Reduction Technology

Table of Contents

Developing a Community Radon Outreach Program: A Model for Statewide Implementation — Panel
M. Jeana Phelps, Kentucky Cabinet for Human Resources

Occupational Safety During Radon Mitigation: Field Experience and Survey Monitorin Results — Posters
Jean-Claude F. Dehmel, S. Cohen & Associates; Peter Nowlan, R.F. Simon Company; Eugene Fisher, U.S. EPA, Office of Radiation Programs

The Effect of Passive Cigarette Smoke on Working Level Exposures in Homes — Posters
Raymond H. Johnson, Jr. and Randolph S. Kline, Key Technology, Inc.; Eric Geiger and Augustine Rosario, Jr., Radon QC

Session III: Measurement Methods

Current Status of Glass as a Retrospective Radon Monitor
Richard Lively, MN Geological Survey, and Daniel Steck, St. John's University

Soil Gas Measurement Technologies
Harry E. Rector, GEOMET Technologies, Inc.

Results from a Pilot Study to Compare Residential Radon Concentrations with Occupant Exposures Using Personal Monitoring
B.R. Litt, New Jersey Department of Environmental Protection; J.M. Waldman, UMDNJ; and N.H. Harley and P. Chittaporn, New York University Medical Center

Rapid Determination of the Radon Profile in a Structure by Measuring Ions in the Ambient Atmosphere
W.G. Buckman and H.B. Steen III, Western Kentucky University

Intercomparison of Activity Size Distribution Measurements with Manual and Automated Diffusion Batteries — Field Test
P.K. Hopke and P. Wasiolek, Clarkson University; E.O. Knutson, K.W. Tu, and C. Gogolak, U.S. DOE; A. Cavallo and K. Gadsby, Princeton University; and D. Van Cleef, NAREL

The Use of Indoor Radon Measurements and Geological Data in Assessing the Radon Risk of Soil and Rock in Construction Sites in Tampere
Anne Voutilainen and Ilona Mäkeläinen, Finnish Centre for Radiation and Nuclear Safety

State Property Transfer Laws Now Include Radon Gas Disclosure — Panel
Michael A. Nardi, The Nardi Group

How to Determine if Radon Measurement Firms are Providing Accurate Readings — Panel
Herbert C. Roy and Mohammed Rahman, New Jersey Department of Environmental Protection

Exploring Software Device Management Routines that Ensure the Overall Quality of Continuous Working Level and Continuous Radon Monitor Performance in a Field Environment — Panel
Richard Tucker, Gemini Research, and Rick Holland, Radonics, Inc.

Use of Grab Samples as a Quality Assurance Tool to Enhance Overall Radon Measurement Accuracy and Reproducibility — Panel
Brian Fimian, Radonics, Inc. and Richard Tucker, Gemini Research

Predicting Long-Term Indoor Radon Concentrations from Short-Term Measurements: Evaluation of a Method Involving Temperature Correction — Panel
T. Agami Reddy, A. Cavallo, K. Gadsby, and R. Socolow, Princeton University

Correlation Between Short- and Long-Term Indoor Radon Concentrations in Florida Houses — Panel
Susan McDonough and Ashley Williamson, Southern Research Institute;
David C. Sanchez, U.S. EPA, Air and Energy Engineering Research Laboratory

Relationship Between Two-Day Screening Measurements of ^{222}Rn and Annual Living Area Averages in Basement and Nonbasement Houses —Panel
S.B. White, N.F. Rodman, and B.V. Alexander, Research Triangle Institute;
J. Phillips and F. Marcinowski, U.S. EPA, Office of Radiation Programs

Characterization of Structures Using Simultaneous Single Source Continuous Working Level and Continuous Radon Gas Measurements — Posters
Brian Fimian and John E. McGreevy, Radonics, Inc.

Radon and Water Vapor Co-Adsorption on Solid Adsorbents — Posters
Neguib M. Hassan, Tushar K. Ghosh, Sudarshan K. Loyalka, and Anthony L. Hines, University of Missouri-Columbia; and Davor Novosel, Gas Research Institute

Calibration of Modified Electret Ion Chamber for Passive Measurement of Radon-222 (Thoron) in Air — Posters
P. Kotrappa and J.C. Dempsey, Rad Elec, Inc.

Session IV: Radon Reduction Methods

Session V: Radon Entry Dynamics

Session VI: Radon Surveys

Factors Associated with Home Radon Concentrations in Illinois
Thomas J. Bierma and Jennifer O'Neill, Illinois State University

Radon in Switzerland
H. Surbeck and H. Völkle, Physics Institute, University Pérolles; W. Zeller, Federal Office of Public Health, Switzerland

A Cross-Sectional Survey of Indoor Radon Concentrations in 966 Housing Units at the Canadian Forces Base in Winnipeg, Manitoba
D.A. Figley and J.T. Makohon, Saskatchewan Research Council

Radon Studies in British Columbia, Canada
D.R. Morley and B.G. Phillips, Ministry of Health; M.M. Ghomshei, Orchard Geothermal Inc.; C. Van Netten, The University of British Columbia

The State of Maine Schools Radon Project: Results
L. Grodzins, NITON Corporation; T. Bradstreet, Division of Safety and Environmental Services, Maine; E. Moreau, Department of Human Services, Maine

The Effect of Subslab Aggregate Size on Pressure Field Extension
K.J. Gadsby, T. Agami Reddy, D.F. Anderson, and R. Gafgen, Princeton University; Alfred B. Craig, U.S. EPA, Air and Energy Engineering Research Laboratory

A Radiological Study of the Greek Radon Spas
P. Kritidis, Institute of Nuclear Technology - Radiation Protection

Seasonal Variation in Two-Day Screening Measurements of 222_{RN} — Posters
Nat F. Rodman, Barbara V. Alexander, and S.B. White, Research Triangle Institute; Jeffrey Phillips and Frank Marcinowski, U.S. EPA, Office of Radiations Programs

The State of Maine School Radon Project: Protocols and Procedures of the Testing Program — Posters
Lee Grodzins and Ethel G. Romm, NITON Corporation; Henry E. Warren, Bureau of Public Improvement, Maine

Results of the Nationwide Screening for Radon in DOE Buildings — Posters
Mark D. Pearson, D.T. Kendrick, and G.H. Langner, Jr., U.S. DOE/Chem-Nuclear Geotech, Inc.

Building Radon Mitigation into Inaccessible Crawlspace New Residential Construction
D. Bruce Harris and A.B. Craig, AEERL and Jerry Haynes, Hunt Building Corporation

The Effect of Subslab Aggregate Size on Pressure Field Extension
K.J. Gadsby, T. Agami Reddy, D.F. Anderson, and R. Gafgen, Princeton University; A.B. Craig, AEERL

Radon Prevention in Residential New Construction: Passive Designs That Work — Posters
C. Martin Grisham, National Radon Consulting Group

Preliminary Results of HVAC System Modifications to Control Indoor Radon Concentrations — Posters
Terry Brennan and Michael Clarkin, Camroden Associates; Timothy M. Dyess, AEERL; William Brodhead, Buffalo Homes

Correlation of Soil Radon Availability Number with Indoor Radon and Geology in Virginia and Maryland — Posters
Stephen T. Hall, Radon Control Professionals, Inc.

Session IX: Radon Occurrence in the Natural Environment

Combining Mitigation and Geology: Indoor Radon Reduction by Accessing the Source
Stephen T. Hall, Radon Control Professionals, Inc.

Technological Enhancement of Radon Daughter Exposures Due to Non-Nuclear Energy Activities
J. Kovac, D. Cesar, and A. Bauman, University of Zagreb, Yugoslavia

A Site Study of Soil Characteristics and Soil Gas Radon
Richard Lively, Minnesota Geological Survey and Daniel Steck, St. John's University

Geological Parameters in Radon Risk Assessment - A Case History of Deliberate Exploration
Donald Carlisle and Haydar Azzouz, University of California at Los Angeles

Geologic Evaluation of Radon Availability in New Mexico: A Progress Report — Posters
Virginia T. McLemore and John W. Hawley, New Mexico Bureau of Mines and Mineral Resources; and Ralph A. Manchego, New Mexico Environmental Improvement Division

Design and Application of Active Soil Depressurization (ASD) Systems in School Buildings — Posters
Kelly W. Leovic, A.B. Craig, and D. Bruce Harris, AEERL; Bobby E. Pyle, Southern Research Institute; Kenneth Webb, Bowling Green (KY) Public Schools

Radon in Large Buildings: Pre-Construction Soil Radon Surveys — Posters
Ralph A. Llewellyn, University of Central Florida

Radon Measurements in North Dakota Schools — Posters
Thomas H. Morth, Arlen L. Jacobson, James E. Killingbeck, Terry D. Lindsey, and Allen L. Johnson, North Dakota State Department of Health and Consolidated Laboratories

Major Renovation of Public Schools that Includes Radon Prevention: A Case Study of Approach, System Design, and Installation; and Problems Encountered — Posters
Thomas Meehan

The State of Maine School Radon Project: The Design Study — Posters
Henry E. Warren, Maine Bureau of Public Improvement and Ethel G. Romm, NITON Corporation

The Effect of Passive Cigarette Smoke on Working Level Exposures in Homes — Posters

Raymond H. Johnson, Jr. and Randolph S. Kline, Key Technology, Inc.; Eric Geiger and Augustine Rosario, Jr., Radon QC

COMPARATIVE DOSIMETRY OF RADON IN MINES AND HOMES: AN OVERVIEW OF THE NAS REPORT

by: Jonathan M. Samet, M.D.
Department of Medicine,
and New Mexico Tumor Registry
University of New Mexico Medical Center
Albuquerque, NM 87131

ABSTRACT

The findings of the recent report by a National Academy of Sciences panel on radon dosimetry are reviewed. The committee was charged with comparing exposure-dose relations for the circumstances of exposures in mines and homes. The community first obtained data on the various parameters included in dosimetric lung models and then selected values that it judged to be best supported by the available evidence. Dosimetric modeling was used to calculate the ratio of exposure to radon progeny to dose of alpha energy delivered to target cells for various scenarios. The committee's modeling shows that exposure to radon progeny in homes delivers a somewhat lower dose to target cells than exposure in mines; this pattern was found for infants, children, men, and women.

The work described in this paper was not funded by the U.S. Environmental Protection Agency and therefore the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

INTRODUCTION

Radon, an inert gas, is a naturally occurring decay product of radium-226, the fifth daughter of uranium-238. Radon decays with a half-life of 3.82 days into a series of solid, short-lived progeny; two of these progeny, polonium-218 and polonium-214, emit alpha particles. When radon progeny are inhaled and these alpha emissions occur within the lungs, the cells lining the airways may be injured and damage to the genetic material of the cells may lead to the development of cancer.

Radon has been linked to excess cases of lung cancer in underground miners since the early decades of the twentieth century. Epidemiologic evidence on radon and lung cancer, as well as other diseases is now available from about 20 different groups of underground miners (1,2). Many of these studies include information on the miners' exposure to radon progeny and provide estimates of the quantitative relation between exposure to progeny and lung cancer risk (2,3); the range of excess relative risk coefficients, describing the increment in risk per unit of exposure is remarkably narrow in view of the differing methodologies of these studies (2).

As information on air quality in indoor environments was collected during the last 20 years, it quickly became evident that radon is ubiquitous indoors and that concentrations vary widely and may be as high as levels in underground mines in some homes. The well-documented and causal association of radon with lung cancer in underground miners appropriately raised concern that radon exposure might also cause lung cancer in the general population. The risk of indoor radon has been primarily assessed by using risk assessment approaches that extend the risks found in the studies of miners to the general population. Risk models that can be used for this purpose have been developed by committees of the National Council on Radiation Protection and Measurements (NCRP) (4), the International Commission on Radiological Protection (5) (1987), and the National Academy of Sciences (Biological Effects of Ionizing Radiation (BEIR) IV Alpha Committee) (1).

Extrapolation of the lung cancer risks in underground miners to the general population is subject to uncertainties related to the differences between the physical environments of homes and mines, the circumstances and temporal patterns of exposure in the two environments, and potentially significant biological differences between miners and the general population (Table 1). A number of these factors may affect the relation between exposure to radon progeny and the dose of alpha-particle energy delivered to target cells in the tracheobronchial epithelium; these factors include the activity-aerosol size distribution of the progeny, the ventilation pattern of the exposed person, the morphometry of the lung, the pattern of deposition and the rate of clearance of deposited progeny, and the thickness of the mucous layer lining the airways.

The activity-aerosol size distribution refers to the physical size distribution of the particles containing the alpha activity. The term "unattached fraction" has historically been applied to progeny existing as ions, molecules, or small clusters; the "attached fraction" designates progeny attached to ambient particles (6). Using newer methods for characterizing activity-aerosol size distributions, the unattached fraction has been identified as ultrafine particles in the size range of 0.5 to 3.0 nm (6). Typically, mines have higher aerosol concentrations than homes and the unattached fraction would be expected to be higher in homes than in mines. Because of differing sources of particles in the two environments, aerosol size distributions could also plausibly differ between homes and mines.

The physical work involved in underground mining would be expected to increase the amount of air inhaled in comparison with the generally sedentary activities of time spent at home. The greater minute ventilation of miners would result in a higher proportion of the inhaled air passing through the oral route, in comparison with ventilation during typical activities in residences. The physical characteristics of the lungs of underground miners, almost all adult males, differ significantly from those of infants, children and thickness of the epithelial layer could also plausibly differ, comparing miners with the general population, because of the chronic irritation by dust and fumes in the mines.

Methods are available for characterizing the effects of these factors on the relation between exposure to radon progeny and the dose of alpha energy delivered to target cells in the respiratory tract. Using models of the respiratory tract, the dose to target cells in the respiratory epithelium can be estimated for the circumstances of exposure in the mining and indoor environments. One of the recommendations of the 1988 BEIR IV Report (1) was that "Further studies of dosimetric modeling in the indoor environment and in mines are necessary to determine the comparability of risks per WLM [working level month] in domestic environments and underground mines". The BEIR IV Report had included a qualitative assessment of the dosimetry of progeny in homes and in mines, but formal modeling was not carried out.

Consequently, the U.S. Environmental Protection Agency asked the National Research Council to conduct a study addressing the comparative dosimetry of radon progeny in homes and in mines. This paper reviews the findings of the recently published report of the committee (Panel on Dosimetric Assumptions Affecting the Application of Radon Risk Estimates). The panel was constituted with the broad expertise, covering radon measurement and aerosol physics, dosimetry, lung biology, epidemiology, pathology, and risk assessment, needed for this task.

THE COMMITTEE'S APPROACH

To address the charge of undertaking further dosimetric modeling, the committee obtained data on the various parameters included in dosimetric lung models that contributed to uncertainty in assessing the risk of indoor radon. The committee not only reviewed the literature, but obtained recent and unpublished information from several investigators involved in relevant research. After completing this review, the committee selected values for parameters in dosimetric models that it judged to be best supported by the available evidence. The committee then utilized a dosimetric model, developed in part by the Task Group of the International Commission for Radiological Protection, to compare exposure-dose relations for exposure to radon progeny in homes and in mines. While the report provides the exposure-dose figures, the committee expressed its principal findings as a ratio, termed K in the BEIR IV report (1). K, a unitless measure, represents the quotient of the dose of alpha energy delivered per unit of exposure in a home to the dose per unit exposure for a male miner exposed in a mine. If the K factor exceeds unity, the delivered dose per unit exposure is greater indoors whereas if it is less than unity, the delivered dose per unit exposure is less indoors.

Factors other than lung dosimetry of radon progeny also introduce uncertainty in extrapolating risks from the studies of underground miners to the general population. The committee briefly reviewed the evidence on cigarette smoking, tissue damage, age at exposure, sex, and exposure pattern. These sources of uncertainty were considered in a qualitative rather than a quantitative fashion.

THE COMMITTEE'S FINDINGS

The committee selected several different sets of exposure conditions in homes and in mines (Table 2,3). The mining environment includes the areas of active mining, the haulage drifts, and less active and dusty areas such as lunch rooms. In some analyses, the values for active mining and haulage ways were averaged to represent typical conditions. Separate microenvironments considered in the home included the living room and the bedroom. Parameters for the living room and the bedroom were averaged to represent a typical scenario for the home. The effects of cooking and cigarette smoking on radon progeny aerosol characteristics were also considered. While the contrast between the home and mining environments was somewhat variable across the scenarios, homes were characterized as having greater unattached fractions and smaller particles. Higher average minute volumes were assumed for the mining environment (Table 2,3).

The committee also examined uncertainties associated with other assumptions in the dosimetric model. Doses to basal and secretory cells in the tracheobronchial epithelium were calculated separately, because all types of cells with the potential to divide were considered to be potential progenitor cells for lung cancer. The committee also compared the consequences of considering: lobar and segmental bronchi rather than all bronchi as the target; radon progeny as insoluble or partially soluble in the epithelium; of breathing through the oral or nasal route exclusively; of varying the thickness of the mucus lining the epithelium and the rate of mucociliary clearance; and cellular hyperplasia leading to thickening or injury causing thinning of the epithelium.

Across the wide range of exposure conditions and exposed persons considered by the committee, most values of K were below unity (Table 4). For both secretory and basal cells, K values indicated lesser doses of alpha energy per unit exposure, comparing exposures of infants, children, men and women in homes with exposures of male miners underground. While the highest values of K were calculated for children, the values for children did not exceed unity, suggesting that children exposed to radon progeny are not at greater risk for lung cancer on a dosimetric basis.

The committee explored the sensitivity of the K factors to underlying assumptions in the dosimetric model. The general pattern of the findings was comparable for secretory and basal cells. The K factors remained below unity regardless of whether the radon progeny were assumed to be insoluble or partially soluble in the epithelium. The K factor was also not changed substantially with the assumption that lobar and segmental bronchi, rather than all bronchi, are the target. Assumptions regarding breathing route also had little impact. After the committee had completed its principal analysis, new data became available suggesting that recent higher values for nasal deposition reported by Cheng et al. (7) might be preferable to lower values from the 1969 report of George and Breslin (8); other new evidence suggested that a value of 0.15 um should be used for aerosol size in the haulage drifts. Inclusion of these two modifications of the committee's preferred parameter values in the dosimetric model reduced the values of K by about 20 percent.

The committee did not attempt to reach quantitative conclusions concerning sources of uncertainty not directly addressed by the dosimetric modeling. It noted the paucity of data on such factors as cigarette smoking, age at exposure and particularly the effect of exposure during childhood, and exposure pattern. The evidence on these factors received detailed review in the BEIR IV report (1) and the present committee did not reach any new conclusions on these sources of uncertainty. The committee also commented on the potential effects of the miners' exposures to dust and fumes while underground. Increased cell turnover associated with these exposures may have increased the risk of radon exposure for the miners.

SUMMARY

The Panel on Dosimetric Assumptions Affecting the Application of Radon Risk Estimates comprehensively reviewed the comparative dosimetry of radon progeny in homes and in mines. The committee's modeling shows that exposure to radon progeny in homes delivers a somewhat lower dose to target cells than exposure in mines; this pattern was found for infants, children, men, and women. This finding was not sensitive to specific underlying assumptions in the committee's modeling. Assuming that cancer risk is proportional to dose of alpha energy delivered by radon progeny, the committee's analyses suggests that direct extrapolation of risks from the mining to the home environment may overestimate the numbers of radon-caused cancers.

REFERENCES

1. National Research Council (NRC). 1988. Health Risks of Radon and Other Internally Deposited Alpha-Emitters. BEIR IV. Committee on the Biological Effects of Ionizing Radiation. Washington, D.C.: National Academy Press.

2. Samet, J.M. Radon and lung cancer. J Natl Cancer Inst. 81: 745-757, 1989.

3. Lubin, J.H. Models for the analysis of radon-exposed populations. Yale J Biol Med. 61: 195-214m 1988.

4. National Council on Radiation Protection and Measurements (NCRP). 1984b. Evaluation of Occupational and Environmental Exposure to Radon and Radon Daughters in the United States. NCRP Report 78. Bethesda, MD: National Council on Radiation Protection and Measurements.

5. International Commission on Radiological Protection (ICRP). 1987. Lung Cancer Risk from Indoor Exposures to Radon Daughters. ICRP Publ. No. 50. Oxford: Pergamon Press.

6. National Research Council. Comparative dosimetry of radon in mines and homes. Panel on dosimetric assumptions affecting the application of radon risk estimates. National Academy Press, Washington, D.C., 1991.

7. George, A.C. and Breslin, A.J. Deposition of radon daughters in humans exposed to uranium mine atmospheres. Health Phys. 17: 115-124, 1969.

8. Cheng, Y.S., Swift, D.L., Su, Y.F. and Yeh, H.C. Deposition of radon progeny in human head airways. In: Inhalation Toxicology Research Institute Annual Report 1988-89. Lovelace Biomedical and Environmental Research Institute, Albuquerque, NM, 1989. LMF-126.

TABLE 1. POTENTIALLY IMPORTANT DIFFERENCES BETWEEN EXPOSURE TO RADON IN THE MINING AND HOME ENVIRONMENTS*

Physical Factors	
Aerosol characteristics	Greater concentrations in mines; differing size distributions
Attached/unattached fractions	Greater unattached fraction in homes
Equilibrium of radon/decay products	Highly variable in homes and mines
Activity Factors	
Amount of ventilation	Probably greater for working miners than for persons indoors
Pattern of ventilation	Patterns of oral/nasal breathing not characterized, but mining possibly associated with greater oral breathing
Biological Factors	
Age	Miners have been exposed during adulthood; entire spectrum of ages exposed indoors
Gender	Miners studied have been exclusively male; both sexes exposed indoors
Exposure pattern	Miners exposed for variable intervals during adulthood; exposure is lifelong for the population
Cigarette smoking	The majority of the miners studied have been smokers; only a minority of U.S. adults are currently smokers

*Taken from Table 1-2 in reference (6).

TABLE 2. ASSUMPTIONS FOR EXPOSURE SCENARIOS ASSUMED FOR MINES AND HOMES*

SUMMARY OF RADON PROGENY AEROSOL CHARACTERISTICS ASSUMED TO REPRESENT EXPOSURE CONDITIONS IN MINES AND HOMES

Exposure Scenario	f_p	AMD of Room Aerosol (µm)	AMD of Aerosol in respiratory tract (µm)
Mine			
Mining	0.005	0.25	0.5
Haulage drifts	0.03	0.25	0.5
Lunch room	0.08	0.25	0.5
Living Room			
Normal	0.08	0.15	0.3
Smoker - average	0.03	0.25	0.5
- during smoking	0.01	0.25	0.5
Cooking/vacuuming	0.05	0.02/0.15+ (15%/80%)	0.02/0.3 (15%/80%)
Bedroom			
Normal	0.08	0.15	0.3
High	0.16	0.15	0.3

*Based on Tables 3-1 and 3-2 in reference 6.

+The radon progeny aerosol produced by cooking/vacuuming has three size modes; 5% of potential alpha energy is unattached, 15% has an AMD of 0.02 m, and 80% has an AMD of 0.15 µm. The 0.02 µm AMD mode is hydrophobic and does not increase in size within the respiratory tract.

TABLE 3. ASSUMPTIONS FOR EXPOSURE SCENARIOS ASSUMED FOR MINES AND HOMES*

LEVELS OF PHYSICAL EXERTION AND AVERAGE MINUTE VOLUMES ASSUMED FOR UNDERGROUND MINERS AND FOR ADULTS IN THE HOME

Exposure Scenario	Level of Exertion	Average $\dot{V}_E$ (liters/min) Man	Woman
Underground Mine			
Mining	25% heavy work/75% light work	31	--
Haulage way	100% light work	25	--
Lunch room	50% light work/50% rest	17	--
Home-Living Room			
Normal and smoker	50% light work/50% rest	17	14
Cooking/vacuuming	75% light work/25% rest	21	17
Home-Bedroom			
Normal and high	100% sleep	7.5	5.3

*Based on Tables 3-1 and 3-2 in reference 6.

TABLE 4. SUMMARY OF K FACTORS FOR BRONCHIAL DOSE CALCULATED FOR NORMAL PEOPLE IN THE GENERAL ENVIRONMENT RELATIVE TO HEALTHY UNDERGROUND MINERS*

Subject Category	K Factor for Target Cells Secretory	Basal
Infant, age 1 month	0.74	0.64
Child, age 1 year	1.00	0.87
Child, age 5-10 years	0.83	0.72
Female	0.72	0.62
Male	0.76	0.66

*Taken from Table 5-1 in reference 6.

Session II:

Radon-Related Health Studies

LUNG CANCER IN RATS EXPOSED TO RADON/RADON PROGENY

F. T. Cross and G. E. Dagle

Pacific Northwest Laboratory, P. O. Box 999, Richland, WA 99352

The lifespan effects of inhaled radon/radon progeny were studied in male Wistar rats. Lung tumors were the principal biological effects observed, consisting primarily of pulmonary adenomas, bronchioloalveolar carcinomas, papillary adenocarcinomas, epidermoid carcinomas, and adenosquamous carcinomas. Four variables appeared to influence the tumorigenic potential of radon progeny in the experiments: 1) radon-progeny cumulative exposure; 2) radon-progeny exposure rate; 3) radon-progeny unattached fraction; and, 4) radon-progeny disequilibrium. Tumorigenic potential increased with: 1)increase in WLM-exposure until lifespan-shortening reversed the trend; 2) decrease in radon-progeny exposure rate; and 3) increase in radon-progeny unattached fraction and disequilibrium. The experimentally derived lung cancer risk of $300/10^6$ animals/WLM was similar to the BEIR IV estimate of $350/10^6$ humans/WLM. The similarities in the human and animal data presently outweigh the differences between them, and suggests the animal model may be useful for studying pulmonary carcinogenic risk in humans.

Planned presentation at The 1991 International Symposium on Radon and Radon Reduction Technology, U. S. Environmental Protection Agency, Philadelphia, PA, April 2-5, 1991.

Work supported by U. S. Department of Energy under DE-ACO-76RLO 1830

Further information regarding this topic may be found in:
Cross, F.T. Evidence of Lung Cancer Risk from Animal Studies. In: Proceedings of the Twenty-fourth Annual Meeting of the National Council on Radiation Protection and Measurement. March 30-31, 1988. pp. 129-140.

STARTLING RADON RISK COMPARISONS

by: JoAnne D. Martin
DMA-RADTECH, INC.
1011 Brookside Road, Suite 155
P.O. Box 3026
Allentown, PA 18106

ABSTRACT

It has long been known that radon causes lung cancer in humans. Radon, in fact, has been called the greatest environmental health threat facing the nation. Despite the fact that people in the United States generally have a great fear of radiation, their attitude toward radon risk has been one of apathy. Traditional radon risk comparison data have, to say the least, been uninspired as well as unmotivating to the public. This study, using publicly-available data, compares radon risk to other pollutants, diseases and health issues that do concern and motivate the public. These health data have been assembled together in a dramatic tabulation, making the radon risk clearly evident and tangible. Results of a nationwide risk opinion survey will also be discussed.

INTRODUCTION

Radiation from nuclear power is perceived by many in the U.S. to be the greatest health risk we face.* Billions of dollars are spent every year on sunscreens to protect us from natural solar radiation. The EPA, the U.S. Surgeon General, NIOSH, The American Lung Association, The American Cancer Society, The World Health Organization, Consumers Union, The National Research Council's Committee On The Biological Effects Of Ionizing Radiation, and The American Medical Association concur that radon in homes and work places is dangerous.

Why, then, is the public so apathetic toward the risk from radon exposure? Public perceptions range from "We don't have radon around here," to "If radon were a significant health threat,...it would be in the news a lot more than it is." Health Physics Society policy-makers have said that radon is not a serious health risk (but neglect to add, "compared to smoking").

Traditional presentations of radon risk data have not motivated the public. Scientific professionals have difficultly communicating technical concepts to the public simply because their style of providing information (logic-based, thinking) is different from how most people gather information and make decisions (emotion-based, feeling). It has been demonstrated that an audience will believe a charismatic, entertaining presentation, whether the information is correct or not (1).

Since the public is not motivated simply by being presented with radon risk information, as has been proven by EPA experience (2), another communication approach is needed. The problem lies not with the quantity of radon risk information presented to the public, but with the quality or relevance of the information.

This study compares the health risks of radon exposure, not to smoking (which provides a perceived beneficial feeling to the smoker), and not to lung x-rays (which people cannot relate to personal risk of death), but to health risks that the public does care about.

Several preliminary statements regarding this study's data must be made:

1. The risk data cited are from publicly-available documents and information services. These data, however, have now

*Risk table courtesy Porter Consultants, Inc., Ardmore, PA.

been arranged into a format that the public understands.
2. It is assumed that the BEIR IV/ICRP/EPA radon risk data are correct. Leading scientists have developed these risk estimates based on a linear no-threshold dose/response relationship, which is admittedly conservative. I must, and do, believe that these scientists know what they are doing.
3. I have not generated any raw risk data or conducted any epidemiological studies. I have only interpreted the already available information.
4. The radon risk estimates assume that lung cancer is the only cause of death. No other potential/possible organ cancers are considered.

HEALTH EFFECTS

RADON KILLS 21,000 AMERICANS (MAYBE AS MANY AS 40,000) EVERY YEAR (3). RADON KILLS 50-100 PEOPLE EVERY DAY, WHICH IS ABOUT 1 PERSON EVERY 20 MINUTES.

This figure is based upon EPA averaging of the BEIR IV and ICRP 50 models, the average residential radon exposure, and a 240 million U.S. population. It also includes a risk of 360 deaths per one million person-WLM, which represents an age-averaged rate for the general population using lifetable and U.S. vital statistics information. It is assumed that the person spends 75% of the day in the radon environment. World-wide risk figures are, of course, much higher.

RADON IN WATER KILLS AT LEAST FOUR AMERICANS EVERY DAY. WATERBORNE RADON MAY CAUSE MORE CANCER DEATHS THAN ALL OTHER DRINKING WATER CONTAMINANTS COMBINED (4,5).

EPA estimates that between 1000 and 1800 people in the U.S. die of lung cancer each year as the result of radon contamination of well water. EPA also estimates that at least eight million people may have undesirably high radon levels in their water supply.

RADON KILLS MORE AMERICANS EACH YEAR THAN THE AIDS VIRUS (i.e., 19,161 DEATHS)(6). UNLIKE AIDS, WHICH CAN ONLY BE TRANSMITTED BY BODILY FLUIDS,** RADON CAN KILL ANYBODY.

AIDS is a disease that has this country panicked. Most areas have state and Federally-funded AIDS task forces, and Congress recently appropriated a three-billion dollar research and treatment package. Because of grass-roots activism, AIDS has gone from being unknown and controversial to a

**Telephone conversation, AIDS Hotline, 1989 data.

household word, yet AIDS doesn't kill as many people annually as does radon.

HUNDREDS OF THOUSANDS OF AMERICANS LIVING IN HOUSES THAT HAVE HIGH RADON LEVELS RECEIVE AS LARGE AN EXPOSURE OF RADIATION YEARLY AS THOSE PEOPLE LIVING IN THE VICINITY OF THE CHERNOBYL NUCLEAR POWER PLANT DID IN 1986, THE YEAR OF THE DISASTER (7).

COMMERCIAL NUCLEAR POWER HAS NEVER KILLED ONE MEMBER OF THE U.S. PUBLIC, YET MILLIONS OF DOLLARS ARE SPENT EVERY YEAR TO PROTECT THE PUBLIC "JUST IN CASE".

Despite widespread fear of nuclear power and radiation, few have discussed the fact that radon exposures produce higher doses than all nuclear plants, and in fact, produce higher doses than dreaded nuclear accidents. Clearly, there is a cost-effectiveness problem here. In fact, if the strict regulations covering nuclear power plants were applied to the famous Watras house, the spending of up to 9.8 million dollars would have been justified by law to eliminate the risk in that one home (7).

THE EPA CONSIDERS INDOOR RADON TO BE ONE OF THE MOST SERIOUS ENVIRONMENTAL CARCINOGENS TO WHICH THE PUBLIC IS EXPOSED (3).

RADON KILLS THOUSANDS MORE AMERICANS EVERY YEAR THAN LEAD, PCB'S, DIOXINS, AND ASBESTOS COMBINED (ASBESTOS, 189 DEATHS; LEAD PAINT, 7 DEATHS; PCB'S AND DIOXINS, NO HUMAN DEATHS EVER CONFIRMED) (3,8). ***

USING ORANGE DYE NUMBER 19 IN LIPSTICK IS BANNED BECAUSE IT HAS A ONE IN 19 BILLION CHANCE OF CAUSING CANCER, BUT THREE OF EVERY 100 PEOPLE EXPOSED TO RADON AT EPA'S ACTION LEVEL WILL DIE OF LUNG CANCER (7).

Radon is a Group A carcinogen, which means that there are human data proving it causes lung cancer in people. Only a few other carcinogens such as asbestos, benzene, and vinyl chloride are proven to kill humans. Group B carcinogens have produced cancer in laboratory animals, and include dioxins, PCB's and chlordane. Group C carcinogens have limited animal data. Only Group A carcinogens have been shown to cause cancer in humans.

Congress has, in the past, directed EPA to regulate toxic and cancer-causing substances (e.g., The Toxic Substances Control Act), and has given EPA authority to set maximum permissible concentrations; thus, there is a precedent for EPA to establish maximum contaminant levels.

***Telephone conversation, National Center for Health Statistics, 1987 data.

Even the lowest estimates of the risk make radon's radioactivity the biggest killer among environmental hazards. The lifetime risk of dying of radon-related lung cancer dwarfs the lethal risks of typical exposures to asbestos, pesticides like ethylene dibromide, and air pollutants like benzene (7).

IT IS ESTIMATED THAT ALMOST AS MANY AMERICANS DIE FROM RADON EACH YEAR AS FROM DRUG-OVERDOSE INCIDENTS (i.e., 24,000), (9, extrapolated to entire population) YET THE PRESIDENT HAS DECLARED A "WAR ON DRUGS", AND THE ADMINISTRATION IS SPENDING BILLIONS OF DOLLARS ON THE "TERRIBLE DRUG PROBLEM".

There is no doubt that drugs are a severe problem, leading to robbery, murder, and other crimes. Drug abuse directly or indirectly affects a large number of people. It must be kept in mind, however, that only one billion of those "drug war dollars" would go a long way toward abating the entire population's radon risk.

RADON KILLS ABOUT AS MANY AMERICANS EVERY YEAR AS DRUNK DRIVING (i.e., 25,000 DEATHS), YET DRUNK DRIVING IS A CRIMINAL OFFENSE. #

RADON KILLS MORE AMERICANS EVERY YEAR THAN HANDGUNS (i.e., 17,000 DEATHS, INCLUDING ACCIDENTS AND CRIMES). ##

Drunk driving and firearm accidents are considered especially heinous by activists because they are preventable. MADD and other organizations mount huge campaigns to prevent these deaths, yet little public or private funding is available to help prevent radon-related deaths, which are also preventable Parents and schools are aloowed to subject children to this cancer-causing substance daily without penalty.

COSTS

A LUNG CANCER PATIENT COSTS AMERICAN SOCIETY THREE THOUSAND DOLLARS A DAY (MINIMUM) IN MEDICAL EXPENSES ALONE, FOR A TOTAL OF 50 TO 60 THOUSAND DOLLARS UNTIL HE/SHE DIES. ADDED TO THIS IS THE COST TO SOCIETY OF REDUCED OUTPUT, SICK LEAVE, ETC. OF ALMOST 100,000 DOLLARS PER CASE. THIS AMOUNTS TO AROUND 2.6 BILLION DOLLARS SPENT EVERY YEAR ON THE RADON VICTIMS WHO DIE (10). ###

ON THE OTHER HAND, THE COSTS TO AMERICAN SOCIETY TO REDUCE RADON TO ACCEPTABLE LEVELS IN ALL EXISTING HOMES IS MUCH LESS THAN THE COST TO SOCIETY FOR SUCH PROGRAMS AS SMOKE DETECTORS AND SEAT BELTS

#Telephone conversation, Mothers Against Drunk Driving Hotline representative, 1989 data.
##Risk table courtesy Porter Consultants, Inc., Ardmore, PA.
###Telephone conversation, Blue Cross/Blue Shield representative.

(i.e., RADON, $15,000-47,000 PER LIFE SAVED; SEAT BELTS AND SMOKE DETECTORS, $250-600,000 PER LIFE SAVED; OTHER ENVIRONMENTAL PROGRAMS, $500,000-7,000,000 PER LIFE SAVED) (11,12).

A Health Physics Society policy-maker suggested that public money spent on radon would be better spent on feeding starving Africans or housing the homeless. This may be true, but it is also naive, as is telling a child to finish his/her dinner because there are starving children in the world. Just as that child's unfinished food would not be used to feed starving children, money that could have been spent on radon is not going to be spent where it "gets the most bang for the buck." No, that money will be spent on a different environmental health hazard that has not killed as many people as radon. Radon is a relatively inexpensive health threat to test for and remediate. Certainly, spending money to test for and remediate radon is a better "deal" than all of this country's other radiation protection programs.

GOVERNMENT ACTION

THE INDOOR RADON ABATEMENT ACT SET A NATIONAL GOAL TO REDUCE INDOOR RADON LEVELS, BUT NO REGULATORY LIMIT. DESPITE WIDESPREAD AVAILABILITY OF TESTING AND MITIGATION SERVICES, LESS THAN 3% OF HOMES, LESS THAN 1% OF WORKPLACES, AND FEW SCHOOLS HAVE BEEN TESTED (12) BECAUSE THERE ARE NO REQUIREMENTS OR INCENTIVES TO DO SO.

The EPA, OSHA, and most states have refused to enforce maximum permissible levels for radon. EPA was directed to set maximum limits for radon in water by 1987, but has yet to do so. Many states still deny that buildings in their state have elevated radon levels and are a health risk. Those states that do have regulatory programs often decrease the amount of testing and mitigation, due to the high cost burden to radon companies to fully subsidize the state program, something that is unprecedented for a public health issue of this magnitude.

IN SWEDEN, ONLY WHEN THE NATIONAL GOVERNMENT BECAME INVOLVED BY SETTING REGULATIONS AND MAXIMUM LIMITS, DID THE MASS MEDIA AND POLITICIANS SHOW INCREASED INTEREST IN THEIR RADON PROBLEM. NOW 53% OF EXISTING HIGH RADON HOMES HAVE BEEN REMEDIATED, AND AN IMPRESSIVE 95% OF NEWLY BUILT HOUSES ARE BELOW THE REGULATED LIMITS (13).

Other major countries of the world are moving to aggressively address the radon issue through regulation. The Atomic Energy Control Board in Canada has set annual exposure limits for radon, for both occupational exposures and the public (14). Under the Euratom Treaty, the Commission of the European Communities has recommended maximum indoor radon levels for its member states. Ireland, Germany, and the United Kingdom have all adopted strict regulatory limits. Only the U.S. lags behind in developing an ambitious program to deal with radon exposures. Other industrialized nations are willing to face the issue head-on and take regulatory action.

PUBLIC OPINION SURVEY RESULTS

As part of the study, I wanted to test public perception of radon when given a few of the above-mentioned statistics. A survey form was developed (Figures 1-2) that asked individuals to rank various health risks in order from 1 (most deaths per year) to 12 (fewest deaths per year). So as not to bias the individual's perception, some attributes of radon were then listed as those from a new environmental health threat called TOXICA, which was stated to:

Kill more Americans each year than the AIDS virus;
Be naturally occurring and found in homes, schools and work places;
Kill one American every 20 minutes;
Kill more Americans every year than asbestos, lead, dioxins and PCB's combined;
Be easily abated or removed for the same cost to society as installing smoke detectors in all homes.

Individuals were then asked to re-rank the risks, this time including TOXICA. The true rankings and number of deaths per year are shown in Figure 2. A set of yes-no questions was also asked, which included:

The Federal government should spend more money on TOXICA than on AIDS. (yes-no)
The Federal government should regulate maximum allowable levels of TOXICA. (yes-no)
The Federal government should require all homes, schools and workplaces to be tested for TOXICA levels. (yes-no)

The survey was distributed to 100 each of: state radiation officials, randomly selected radon companies nationwide, people in Indiana, people in Eastern Pennsylvania, and medical doctors in Eastern Pennsylvania.

The results of this survey are shown in Figures 3-6. The overall response rate was 7.6%, with state radiation officials as the highest respondents (17%). A large majority ranked TOXICA as one of the top three health threats, while very few people ranked radon in the top three (Figure 3). Although no one ranked radon as the number one threat, 17% overall ranked TOXICA as number one (Figure 4). Several state radiation officials realized that radon and TOXICA were one and the same, and noted this on their surveys. A majority of the "public" (i.e., excluding radon companies and state officials) ranked radon as one of the three least significant health threats, while few respondents ranked TOXICA in the last three (Figure 5).

A strong majority of all respondents felt that more Federal funds should be spent on TOXICA than on AIDS, maximum regulatory levels should be set for TOXICA, and testing should be required by the Federal government (Figure 6). Conclusion: TOXICA is perceived as a significant health threat, while radon is not.

More extensive research is now proposed, including:

1. Using a larger sample number, and cross-section the U.S., in order to better approximate overall public perception.
2. Gauging the response when the TOXICA name for the contaminant is changed to something more innocuous.
3. Effect on perception of natural or man-made risks.
4. Determining public response to funding considerations. Do attitudes change if homeowners have to pay for TOXICA, or if other government programs must be cut in order to fund a TOXICA program?
5. What different communication styles are most effective? In what way should information be presented in order to generate public awareness?

SUMMARY

Radon poses a greater health risk than any other environmental pollutant. While Federal agencies have been tip-toeing around the issue (so as not to overly alarm the public), more people in the U.S. die each year from radon than from most other "scary" risks, including the AIDS virus. A public opinion survey shows that radon by another name is thought to be dangerous. A key point to note is that people also feel that the government would take the necessary steps to protect them if radon were really dangerous.

A new approach to informing the public is necessary; perhaps a little fear would prompt some action. Should not the public be concerned (upset/disturbed) if an American dies every 20 minutes from a preventable disease?

Regulation is needed. The U.S. lags far behind other leading industrialized nations in addressing the radon issue. From a cost effectiveness standpoint, a fraction of the money currently spent to protect the public from possible nuclear power plant accidents would save many more lives if spent on solving the radon problem.

It is hoped that this study's information will be used for public information, to influence government policy and spending, and to inform those in medical and other health related fields. If the information is shocking, if it makes people feel uncomfortable, so much the better. A spark of controversy may wake people up and make them pay attention to this serious health issue.

REFERENCES

1. Mossman, K.L. Nuclear literacy. Health Phys. 58:639-643; 1990.

2. Fisher, A. Radon risk communication research: practical lessons. Air and Waste. To be published 1990.

3. Schmidt, A., et al. EPA's approach to assessment of radon risk. In: EPA international radon symposium. Atlanta, GA; February, 1990.

4. Lamarre, B.L. Radon in water aeration system operational performance. In: EPA international radon symposium. Atlanta, GA; February 1990.

5. Fit to Drink? Consumer Reports. January 1990.

6. U.S. Department of Health and Human Services, Centers for Disease Control. HIV/AIDS surveillance report. Washington, DC; April 1990.

7. Kerr, R.A. Indoor radon: the deadliest pollutant. Science. 240:606-608; 1989.

8. Cassens, B.J., ed. Preventive medicine and public health. Chapter 13. New York: John Wiley and Sons; 1987.

9. National Institute on Drug Abuse. Data from the Drug Abuse Warning Network (DAWN). Series 1, No. 8; Rockville, MD; 1989.

10. US Environmental Protection Agency. Report to Congress on indoor air quality, Vol. II, assessment and control of indoor air pollution. EPA/400/1-89/001C: 5-9, 5-14; 1989.

11. Strom, D.J.; Mallon, Jr., J.B. A cost-effectiveness comparison of private-sector radon remediation with traditional radiation protection activities. In: EPA international radon symposium. Atlanta, GA; February 1990.

12. EPA's radon action program: accomplishments and future challenges. In: EPA international radon symposium. Atlanta, GA; February 1990.

13. Swedjemark, G.A., and Makitalo, A. Recent Swedish experiences in Rn-222 control. Health Phys. 58:453-460; 1990.

14. Bhawani, P. Radon in buildings. Canadian Centre for Occupational Health and Safety; February 1989.

15. O'Riordan, M.C. Europe moves on radon. Health Phys. 58:759; 1990.

The work described in this paper was not funded by the U.S. Environmental Protection Agency and therefore the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

This is side one. Please begin on this side.

SURVEY/QUESTIONNAIRE

We are constantly being bombarded with information regarding health threats. Every day we read about acid rain, high blood pressure, assault rifles, alcohol, drunk driving and the like. How does this affect the way we think? We're trying to find out. This survey is being sent to you as part of a study which is attempting to determine how significant new information acts to change an individual's opinion. Your answers will be used to help influence legislation and government policy. The survey is divided into two parts. Part One, on this page, lists 12 different health and environmental dangers. You are asked to rank, in the order you believe is most important, the seriousness of each threat. (1 causes the most deaths, 12 the least). On the reverse side is a similar list. This one, however, imagines that a new environmental threat, TOXICA, has been discovered. You are again being asked to rate the relative danger of each threat, this time including TOXICA among them.

Please rank these risks 1 through 12 according to your perceptions of deaths per year in the United Sates (#1 = most deaths per year).

HANDGUNS ______	LEAD ______	ASBESTOS______
AIDS VIRUS ______	PCB'S ______	DIOXINS ______
DRUG ABUSE______	DRUNK DRIVING ______	SMOKING ______
RADON ______	NUCLEAR POWER______	ALCOHOL ______

Please check your feelings below:

I believe that the Federal Government should spend more money on eliminating all of the environmental and health dangers listed above_____ only the top three _____ six _____ nine_____ none_____ .

I believe that the Federal Government should regulate maximum allowable levels of all of the environmental and health dangers listed above _____ only the top three_____ six _____ nine_____ none_____ .

I believe that the Federal Government should require all citizens to participate in safety programs designed to eliminate these environmental and health hazards from homes, schools and workplaces. Yes _____ No_____.

Please turn this form over and complete the other side.

When you have completed this survey, please fold it so that the Environmental Risk Survey address is showing. Staple the survey and drop it in the mail. Thank you for your participation in this survey. If you desire a copy of the survey results, please send a self-addressed, stamped envelope to the address on the other side. Results will be available in the fall of 1990.

FIGURE 1

This is Side Two. Please begin on Side One.

Part Two: How does the introduction of new information affect your attitude about deaths per year?

A new environmental threat has been discovered. The Environmental Protection Agency has named it TOXICA. In less than a year, it has been discovered that TOXICA:

---Kills more Americans each year than the AIDS virus;
---Is nautrally occurring (not man-made), and is found in homes, schools and workplaces;
---Kills one American every 20 minutes;
---Kills more Americans every year than Asbestos, Lead, Dioxins, and PCB's combined;
---Can be easily abated or removed for about the same cost to society as installing smoke detectors in all homes.

Please re-rank these risks 1 through 13 according to your perception of deaths per year in the United States (#1 = most deaths per year). Remember to take the environmental threat TOXICA into account in your deliberations.

HANDGUNS	8	17,000	LEAD	10	7	DIOXINS	13	0
AIDS VIRUS	7	19,000	PCB's	12	0	RADON	(6) 5*	21,000
DRUG ABUSE	4	24,000	DRUNK DRIVING	3	25,000	ASBESTOS	9	189
TOXICA	(5) 6*		NUCLEAR POWER	11	1	ALCOHOL	2	100,000
SMOKING	1	120,000						

Please check your feelings below:

I believe that the Federal Government should spend more money on eliminating all of the environmental and health dangers listed above_____ only the top three _____ six _____ nine _____none _____.

I believe that the Federal Government should regulate maximum allowable levels of all of the environmental and health dangers listed above _____only the top three_____ six _____nine _____ none _____

I believe that the Federal Government should require all citizens to participate in safety programs designed to eliminate these environmental and health hazards from homes, schools and workplaces. Yes _____ No _____.

I believe the Federal Government should spend more money on TOXICA than on AIDS. Yes _____ No_____.

I believe the Federal Government should regulate maximum allowable levels of TOXICA. Yes _____ No _____ .

I believe the Federal Government should require all homes, schools and workplaces to be tested for TOXICA levels. Yes _____ No _____ .

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST-CLASS MAIL PERMIT NO. 0065 COOPERSBURG, PA

POSTAGE WILL BE PAID BY ADDRESSEE

Environmental Survey
P.O. Box 288
Coopersburg, PA 18036-9990

FIGURE 2

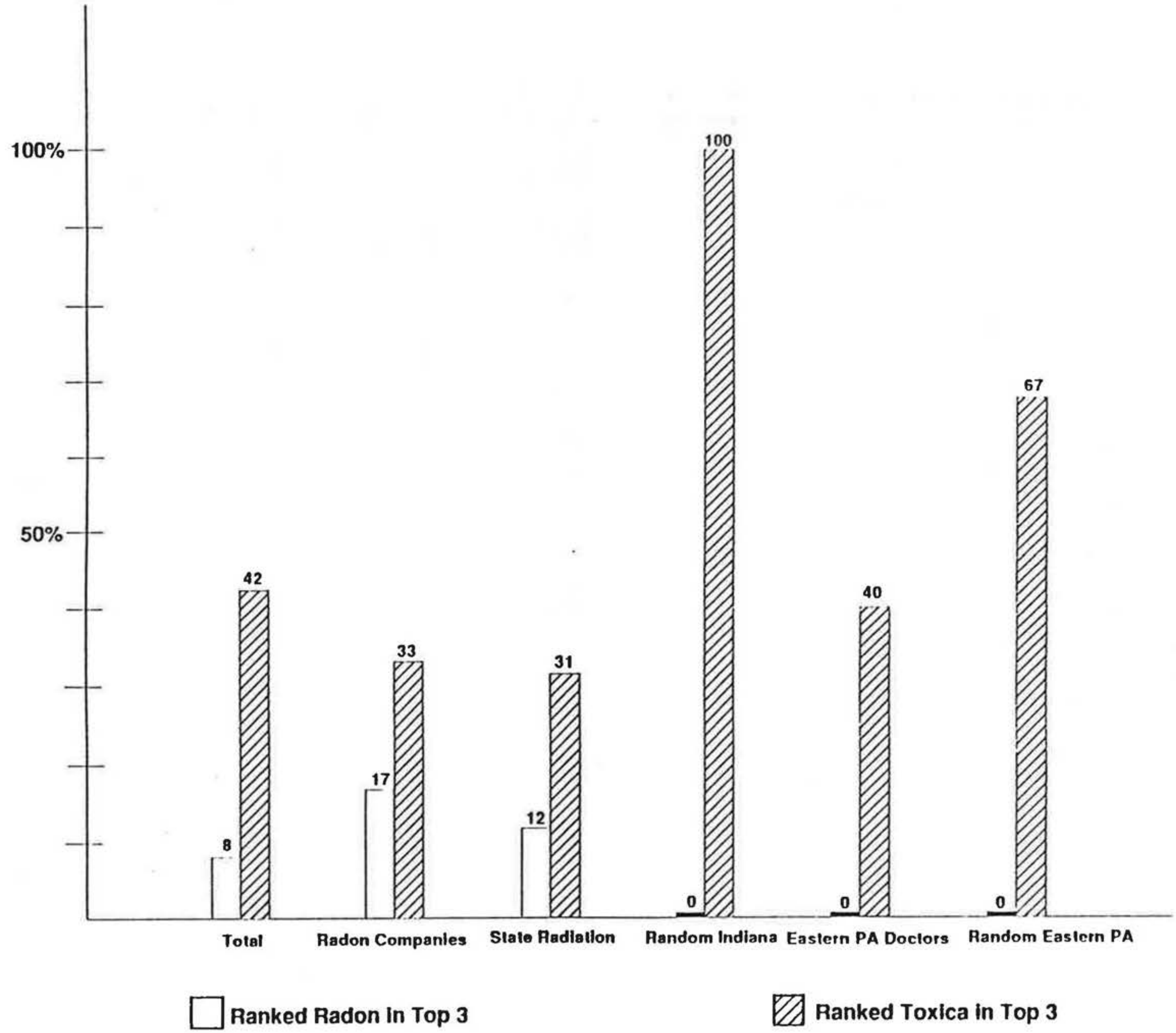
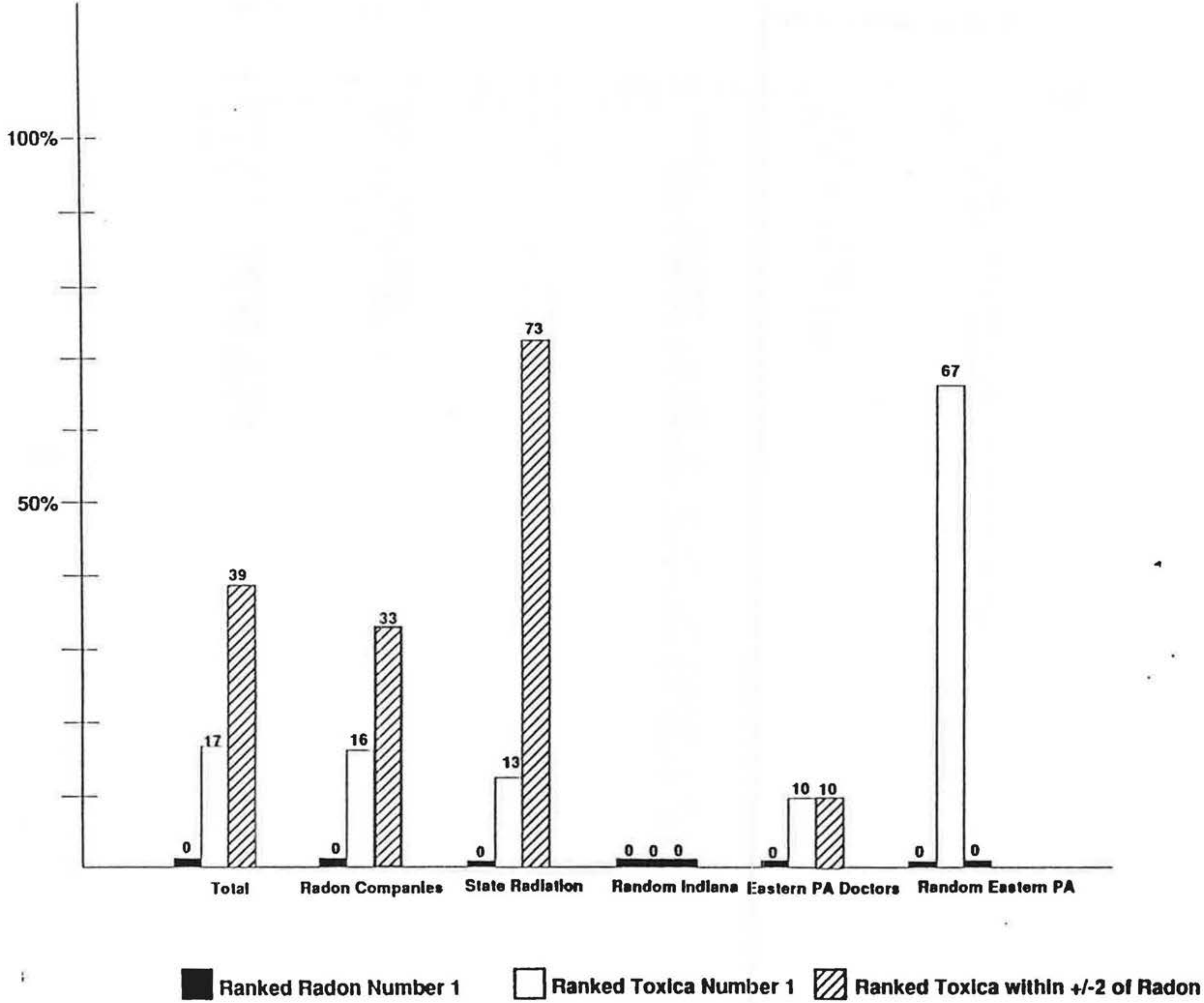

100%
50%
100
67
42
40
33
31
17
12
8
0
0
0
Total
Radon Companies
State Radiation
Random Indiana
Eastern PA Doctors
Random Eastern PA
Ranked Radon In Top 3
Ranked Toxics In Top 3

Figure 3



100%
50%
39
17
0
33
16
0
73
13
0
0 0 0
10 10
0
67
0
0
Total
Radon Companies
State Radiation
Random Indiana
Eastern PA Doctors
Random Eastern PA
Ranked Radon Number 1
Ranked Toxica Number 1
Ranked Toxica within +/-2 of Radon

Figure 4

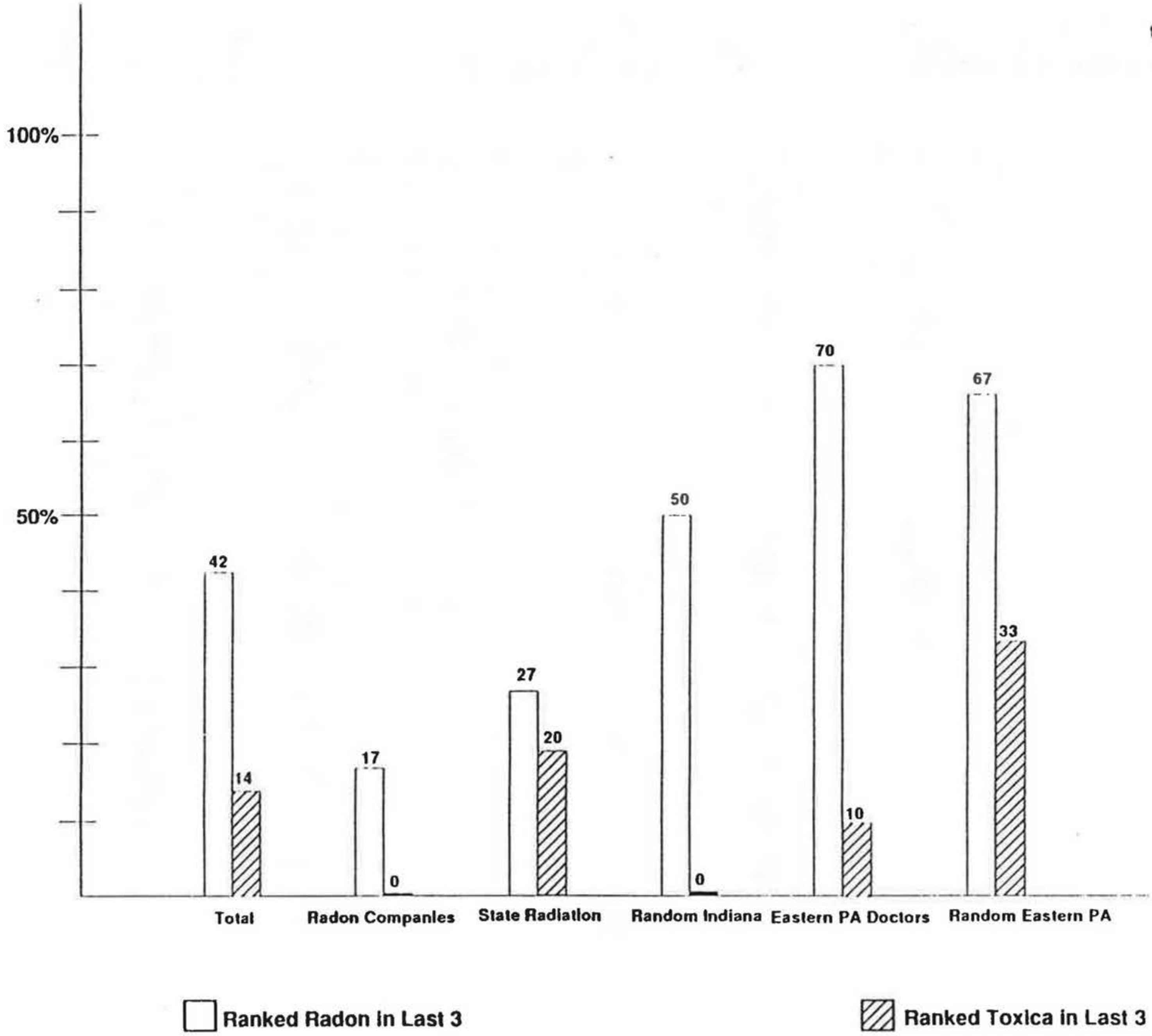
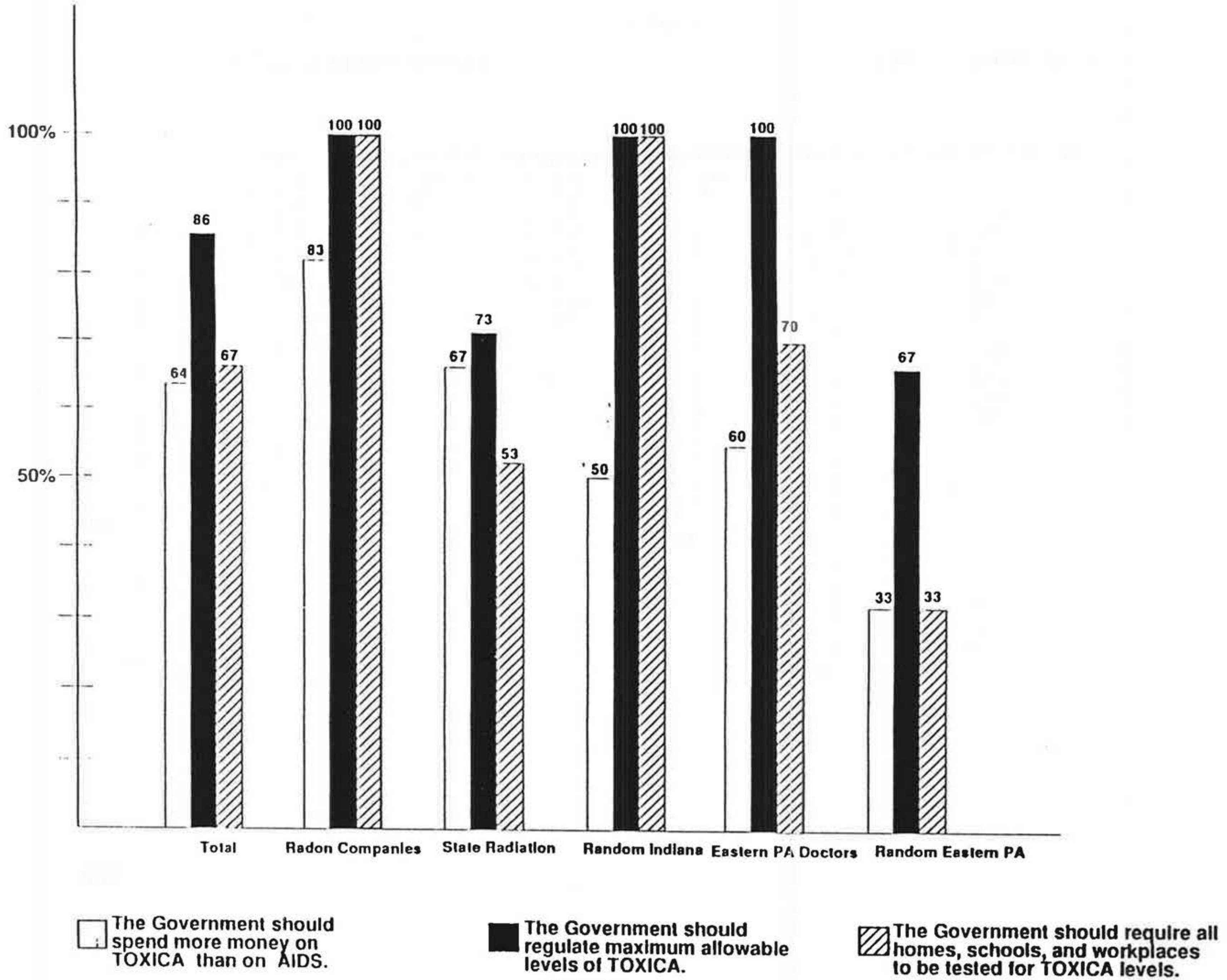

100%
50%
42
14
17
0
27
20
50
0
70
10
67
33
Total
Radon Companies
State Radiation
Random Indiana
Eastern PA Doctors
Random Eastern PA
Ranked Radon in Last 3
Ranked Toxica in Last 3

Figure 5



100%
50%
86
64
67
83
100 100
67
73
53
50
100 100
60
100
70
33
67
33
Total
Radon Companies
State Radiation
Random Indiana
Eastern PA Doctors
Random Eastern PA
The Government should spend more money on TOXICA than on AIDS.
The Government should regulate maximum allowable levels of TOXICA.
The Government should require all homes, schools, and workplaces to be tested for TOXICA levels.

Figure 6

EXPANDED AND UPGRADED TESTS OF THE LINEAR-NO THRESHOLD THEORY FOR RADON-INDUCED LUNG CANCER

By: Bernard L. Cohen
University of Pittsburgh
Pittsburgh, PA 15260

ABSTRACT

BEIR-IV gives lung cancer risks vs. radon exposure, R, for smokers and non-smokers. Summing these over the population gives the mortality rate, m, as a function of R and S, the fraction of the population that smokes. From data on R and S, m(BEIR) can be calculated for each state and compared with observed values, m(obs). Their ratio, m(BEIR)/m(obs), increases rapidly with increasing R, indicating that the R-dependence of m(BEIR) is much too strong; in fact, if this R-dependence is reduced to zero, a large discrepancy remains. All attempts to explain the discrepancy fail, and it is shown to apply to all other recognized theories.

Using counties rather than states gives 20 times as many recognized data points, but is limited by the lack of smoking information. Multiple regression is used involving 17 potential socioeconomic confounding factors. The slope of m vs. R is negative, a sharp discrepancy with the predicted strong positive slope. Data are stratified and segmented in over a hundred different ways, but the large discrepancy is always found.

The limitations of this county study due to the fact that it is an "ecological study" are investigated. It is shown that they are not nearly strong enough to explain the discrepancy.

A. A MATHEMATICALLY RIGOROUS TEST OF THE BEIR-IV AND OTHER RISK ESTIMATES

Table 2-4 of the BEIR-IV Report gives the risk of lung cancer to smokers, r_s, and to non-smokers, r_n, as

$$r_s = a_s + b_s R' \tag{1a}$$
$$r_n = a_n + b_n R' \tag{1b}$$

where R' is their annual radon exposure, and a_S, a_n, b_S, and b_n are constants. The number of deaths expected in a state each year, N_s and N_n, is obtained by summing (1) over all persons in the state, p smokers and q non-smokers, which gives

$$N_s = pa_s + pb_s\left(\frac{\Sigma R'}{p}\right) = pa_s + pb_s R$$
$$N_n = qa_n + qb_n\left(\frac{\Sigma R'}{q}\right) = qa_n + qb_n R$$

where R is the average radon exposure, assumed here to be equal for smokers and non-smokers. The state mortality rate, m, is the total number of deaths per year divided by the population,

$$m = \frac{N_s + N_n}{p+q} = \frac{pa_s + qa_n}{p+q} + \frac{pb_s + qb_n}{p+q} R$$

or in terms of the fraction of the population that smokes, $S = p/(p + q)$

$$m = Sa_s + (1-S)a_n + [Sb_s + (1-S)b_n]R \tag{2}$$

Averaged over each person's lifetime, the annual risk is the lifetime risk, given in Table 2-4, divided by the life expectancy given on p. 55 of BEIR-IV, which yields (in units of $10^{-5}y^{-1}$) $a_S = 178$, $a_N = 15.9$, $b_S = 17.8$, $b_N = 1.75$ for males, and $a_S = 76.7$, $a_N = 7.9$, $b_S = 8.4$, $b_N = 0.87$ for females, with R measured in units of $R_O = 37$ Bq m^{-3} (= 1.0 pCi L^{-1}) = 0.2 WLM y^{-1} (WLM = working level months).

Values of S for each state are available from the Bureau of Census 1985 Current Population Survey of 114,000 persons, and mean radon levels for each state are available from the University of Pittsburgh Data File. Thus, values of m, m(BEIR-IV), can be calculated for each state. These can then be compared with the actual (observed) age-adjusted lung cancer rates, m(obs), for which we use the EPA compilation for 1970-1979. For purposes of discussion, we consider fits of m(BEIR-IV) and m(obs) vs R to

$$m = a + bR \tag{3a}$$

and their ratios vs. R to

$$\frac{m(BEIR-IV)}{m(obs)} = A + BR \tag{3b}$$

where a, b, A and B are adjustable constants.

The ratio m(BEIR-IV)/m(obs) plotted vs the mean radon level, R, has a positive slope B differing from zero by 7.7 and 7.8 SD for males and females respectively. This means that the positive slope of m vs R given by the theory is far too strong. To break the problem into its components, a plot of m(BEIR-IV) vs R is fit by a line with slope, b, given by b = 3.8 ± 1.9 for males and 2.5 ± 0.77 for females, while a plot of m(obs) vs R is fit by a line with negative slope, b = -9.8 ± 2.1 for males and -2.6 ± 0.6 for females.

In principle, at least, our derivation of (2) was by rigorous mathematics and therefore not subject to the problems in epidemiological studies. In fact our treatment is basically a simple application of "the scientific method": a theory makes a prediction which is tested by observation; if they do not agree, the theory must be modified or abandoned.

In practice, there are several "loose ends" that must be considered. The principal one is migration--correcting for this changes the slope B from 0.30±0.039 (1 SD) to 0.28±0.040 for males, and from 0.64±0.082 to 0.595±0.082 for females. If the retirement states FL, CA, and AZ are removed from the data base, B becomes 0.28±0.042 for males and 0.56±0.092 for females. Correcting for migration does very little to reduce the discrepancy.

Other loose ends are validity of the data which has been treated elsewhere, and which will be finally settled by the National Radon Survey; use of 1970-79 lung cancer statistics with 1985 statistics on smoking, while BEIR-IV risks are based on 1981-84 lung cancer data, which will be largely settled when more recent lung cancer statistics become available; and assuming average radon exposure is the same for smokers and non-smokers, which is corrected for elsewhere.

We conclude that the discrepancy with BEIR-IV is real and very large. It is shown that this discrepancy is not appreciably reduced by using other risk estimates, or by considering effects of potential confounding socioeconomic factors (pcf).

B. MULTIPLE REGRESSION ANALYSIS OF DATA ON U.S. COUNTIES

There is a great advantage in using counties rather than states in this type of study since data are available on 913 counties vs. only 47 states (excluding AZ, CA, FL). This allows inclusion of many more pcf and gives much better statistical certainty. It has the disadvantage that data are not available on smoking frequency by counties, so the "mathematically rigorous" test cannot be made. But smoking in the state, S', is used as a pcf; hopefully the socioeconomic pcf will largely represent the variations within the state.

In multiple regression, we seek the best fit to

$$m=a+bR+c_1F_1+c_2F_2+...+c_{17}F_{17}+c_sS' \quad (4)$$

where F_1, F_2,----, F_{17} are the values of 17 selected socioeconomic pcf, and a, b, c_i are constants determined by fitting the data. With 913 sets of data, 20 constants is not excessive for high statistical significance.

In fitting the data, S' is the most important variable and c_s is positive as expected. However, the values of b in (4) are quite insensitive to whether or not S' is included: -1.59 ± 0.37 vs. -1.63 ± 0.39 for males, and -0.62 ± 0.13 vs. -0.67 ± 0.13 for females. This indicates that the other pcf act as surrogates for smoking. Since smoking is well known to be the most important factor in causing lung cancer, this suggests that the number and variety of pcf is sufficient to act as surrogates for any other pcf that has not been included.

The most important aspect of the above is the values of b which differ from the BEIR-IV prediction (corrected for migration) +4.5 for males and +1:1 for females by 16 and 13 standard deviations respectively. This is a tremendous discrepancy between theory and observation.

Extensive studies were made of effects of stratifying the data into sub-groups. Data were stratified into quintiles on the basis of each of the socioeconomic pcf in turn and a complete multiple regression analysis was done on each quintile. For these (17 pcf x 5 quintiles x 2 sexes=) 170 analyses, 94% had negative values of b and the largest positive b was less than 30% of the BEIR prediction. The average value of b was-1.18 for males and -0.56 for females. For the 5 quintiles generated by stratifying on a single pcf, in all cases the average b was negative, and never smaller than-0.88 for males and -0.40 for females. The slope b is negative if we confine our attention only to the big city counties or only to the most rural counties, only to the highest income or only to the lowest income counties, only to counties with the oldest median age or only to the counties with the youngest median age, etc., etc.

When the data are stratified on geography, a substantial change results: the average value of b for all geographic areas is reduced to zero. That is, the negative slopes are explained by a systematic negative relationship between m and R for the regions of the nation. This relationship cannot be explained by smoking patterns, and no other explanation is easy to concoct. It might be due only to chance, since there are only 7 regions, in which case this regional correlation is not significant. But even a zero value of b represents a very large discrepancy with theory.

In the remainder of this study, stratification on geography was retained. Finer stratification on geography was tried by analyzing the data separately or each of the 18 states in which we have data on at least 20 counties. (The number of pcf must be dramatically reduced for this.) The average values of b were -0.11 for males and -0.46 for females.

Double stratification was tried by stratifying the data for each national region on the basis of each important socioeconomic pcf in turn. The b values averaged over strata and regions for each of these stratifications was essentially the same as those obtained from stratification by regions only.

As a check on the validity of our radon data, similar studies were carried out using data from the EPA surveys in the 22 states for which they were available. It was assumed that exposures were 0.5 times basement measurements. The slopes b for the entire data set and for individual states were essentially the same as those obtained by analyzing our data for the same 22 states.

In summary, we find a gross and statistically undisputable discrepancy between the predictions of BEIR-IV and observed lung cancer rates in U.S. counties: the theory predicts a substantial increase in lung cancer mortality with increasing radon exposure, while observations corrected for smoking and a wide variety of potential socioeconomic confounding factors indicates a decrease, or after allowance for a systematic geographical effect which is not understandable, a null dependence.

C. PROBLEMS ARISING FROM THE FACT THAT OUR STUDY OF COUNTIES IS AN ECOLOGICAL STUDY

Our study of counties outlined in Sec. B is what epidemiologists call an "ecological study," and there is a large literature on the hazards and shortcomings of ecological studies. One such problem is that an ecological study of large groups of people ignores the fact that only small sub-groups may be at risk--effectively the wrong people are being studied--but it has been shown that this problem does not apply to a linear-no threshold theory. The other normally cited problem is that ecological studies are especially susceptible to confounding relationships. We consider that problem here.

We assume that Eq. (2) is the true relationship, and consider the degree to which an ecological study based on Eq. (4) fails to give the correct result. In order to understand what cam be expected from such an ecological study, consider the average value of m, $\bar{m}$, for all counties with a given value of R, say R_1. This can be calculated by use of (2). If S is not correlated with R, the distribution of S-values for those counties is the same as the distribution for all counties whence,

$$\bar{m}(R_1)=[\bar{S}a_s+(1-\bar{S})a_m]+[b_s\bar{S}+b_n(1-\bar{S})]R_1 \tag{5}$$

where $\bar{S}$ is the national average value for S, which is known. Since this relationship is valid for each value of R_1, the best fit to all of the data would depend on R in accordance with (5) with the variable R replacing R_1. Thus, b would be

$$b=b_s\bar{S}+b_n(1-\bar{S}) \tag{6}$$

Since b_s and b_n are known from the theory and $\bar{S}$ is known, determining b from an ecological study and application of (6) gives a test of the theory. Note that even a simple regression of m on R gives the correct value of b if there is no correlation between R and S.

If there is a strong correlation between R and S, this is no longer valid. For example, if we consider $b_s >> b_n$ (actually $b_s = 10b_n$) and $S=k/R$, according to (2), there is no dependence of m on R, whence an ecological study with simple regression of m on R would give zero slope, a large discrepancy with (6). This discrepancy would be reduced by a multiple regression of m on R and S, but clearly (4) is not a good representation of (2) with $S=k/R$, so there would still be a substantial discrepancy.

If one examines the literature on the hazards of ecological studies due to confounding, one finds that they always arise from this type of correlation. Typically the examples given are based on concocted data involving 3 to 5 data points with these correlations built in. With so few data points, such correlations can arise by chance -- there is nothing wrong with these examples. However, when there are many hundreds of data points, the possibility of strong chance correlations becomes vanishingly small. They can only arise from causes that can hopefully be traced down and evaluated. That is the situation we have here. We will consider what correlations between R and S are credible, and we will evaluate their effects quantitatively, using data for males. Since we assume that (2) is the true relationship, we must have values of S for each county. We derive these by use of models which incorporate variable correlations between R and S. We use (2) with these S-values to calculate m for each county, and use that calculated value (rather than the observed value) of m in our regression analysis. We then investigate the degree to which the b-value obtained from the regression analysis compares with that for no correlation between R and S. These calculations are done with our 913 county data file using the R and socioeconomic pcf--but not the observed m or S'--for each county.

Our first model, which includes our estimate of the realistic situation, derived from our other studies, involves the following effects:

(1) Urban areas have more smoking and hence about 20% more lung cancer than rural areas, but urban houses have about 25% lower radon levels.

(2) Houses of smokers have about 10% lower radon levels than houses of non-smokers.

(3) It is believed that X% of lung cancer is due to air pollution, and areas with high air pollution have about 30% lower radon levels than areas of low air pollution. EPA estimates as a national average X=1.5%, but we take X=25% for smokers and 75% for non-smokers in order to have an appreciable effect. This effect is treated as an add-on, independent of R, S, or m.

The mathematics is complicated by including four groups, rural and urban smokers and non-smokers, rather than two (smokers and non-smokers) as in the derivation of (2), but the calculation is straightforward. We call the numerical estimates given above the "index values." With no correlations, b=4.59; with index values, b=3.92; with 2, 4, 6, and 10 times the index values b=3.08, 1.70, 0.82, and -0.06 respectively.

We conclude that the realistic effects we have introduced reduce the positive value of b predicted by the theory by only 15%. In order to reduce b to zero, which is the maximum observed value, all of these effects would have to be 10 times larger than we know them to be.

There could be other confounding effects, but after years of study, we have found none that are comparable to these, let alone 10 times stronger.

Our second model, run on our file for states, explores the effect of an unrealistically strong direct correlation between R and S, given by

$$S=0.4-0.2r/N \tag{7}$$

where r is the ranking of the state by radon level, R, and N is the total number of states. The constants reflect the fact that smoking frequencies for states are all in the range 0.2 to 0.4 for males. We use (7) to calculate m, which is then used in the regression analyses.

With this very strong negative correlation between R and S, a single regression of m on R gives a very negative slope, b=-9.1. But a double regression on R and S, fitting the data to

$$m=a+bR+cS$$

gives b=+3.2. If we let S be the same for all states, there is no correlation between R and S and either single or double regression gives b=+4.3.

We see that even this highly unrealistically strong correlation between R and S removes only a small fraction of our discrepancy.

SUMMARY

A plot of lung cancer mortality rate, m, vs. radon exposure, R, for various states or counties shows a strong tendency to decrease with increasing R whereas theories lead one to expect a substantial increase with increasing R. The discrepancy in slope of the best fit line is many orders of magnitude. Our purpose is to try to understand this discrepancy.

The BEIR-IV theory gives risks to individuals, differing for smokers and non-smokers. When these are summed over the population, one obtains predictions of the lung cancer mortality rates as a function of R and S, the fraction of the population that smokes. Since R and S are known for each state, the theory can be tested directly on those data. It fails drastically; the dependence on S is not nearly strong enough to change the dependence on R from strongly positive to strongly negative. In principle, at least, this study is mathematically rigorous, and hence not subject to the normal problems of epidemiology. It is shown that any theory which gives a risk to individuals increasing with R, and with smoking as the only other variable, encounters this same discrepancy with observation. All known theories fit this description.

An alternative test is to use data for counties, which has the advantage of 20 times as many data points, but the disadvantage of being an ecological study because smoking data are not available for counties. The problem is treated by multiple regression analysis involving 17 socioeconomic potential confounding factors (pcf). The result gives a slope of m vs. R with negative slope differing from the substantial positive slope predicted by BEIR-IV by 15 S.D. The data are stratified in various ways, but similar discrepancies are found for all individual subsets of the data. The validity of the data is tested by comparing with similar analyses of EPA data, and good agreement is found.

Since this is an ecological study, the problems ascribed to ecological studies are examined, and it is shown that the only ones applicable here would be due to correlations between R and S. From other studies, there is substantial information about such correlations, but when this information is applied, the discrepancy is reduced by only 15%, and all effects would have to be 10 times larger to remove the discrepancy. Even an unrealistically strong direct correlation between R and S removes only one-third of the discrepancy.

If this discrepancy between theory and observation cannot be explained, the only rational alternative is to abandon the linear-no threshold theory, recognizing that it grossly over-estimates the cancer risk from low level radiation.

#5465

ESTIMATING RADON LEVELS FROM Po-210 IN GLASS

by : J. Cornelis*, H. Vanmarcke**, C. Landsheere* and A. Poffijn*
* Nuclear Physics Laboratory, State University of Gent
Proeftuinstraat 86, B-9000 Gent, Belgium
** Radiation Protection, Nuclear Research Center, S.C.K./C.E.N.
Boeretang 200, B-2400 Mol, Belgium

ABSTRACT

The α-decay of Po-210 may become a useful indicator of the radon exposure during the last decades. The uncertainties associated with this technique were studied both experimentally and theoretically.

The depth distribution of absorbed Pb-214 and Pb-210 in glass is calculated using the theory of Lindhard for low energy heavy ions. It is found that 29.8 % of the absorbed Po-214 reappears at the glass surface after α-decay. The surface layer in which the decay products are absorbed is less than 100 nm. Measurements of the α-activity of Po-214 show that cleaning the glass once removes 85% of the deposited activity.

Room model calculations indicate that the ratio of the Po-210 surface activity to the radon air activity is about equally dependent on the deposition constant of the unattached decay products and on the attachment rate. The presence of aerosol sources, for instance, lowers the surface activity by a factor of two. Experimental investigations prove this finding.

INTRODUCTION

Lively in 1987 (1) and Samuelsson in 1988 (2) put up the idea of using the α-activity of Po-210, absorbed in vitreous glass, to determine the long term radon exposure in the living environment. The technique may be used as a retrospective exposure measure, for instance, in epidemiological studies.

The parameters influencing the absorbed and deposited Po-210 activity are indicated in figure 1. A fraction of the airbone Po-218, Pb-214, Bi-214, Po-214 and Pb-210 deposits on macroscopic surfaces. Half of the deposited activity recoils into the surface, upon α-decay, forming a thin absorbed layer. Subsequent α-decay makes a fraction of the absorbed activity to reappear at the surface. Household cleaning largely wipes away the deposited activity. The values of the transfer probabilities will be assessed in the next sections.

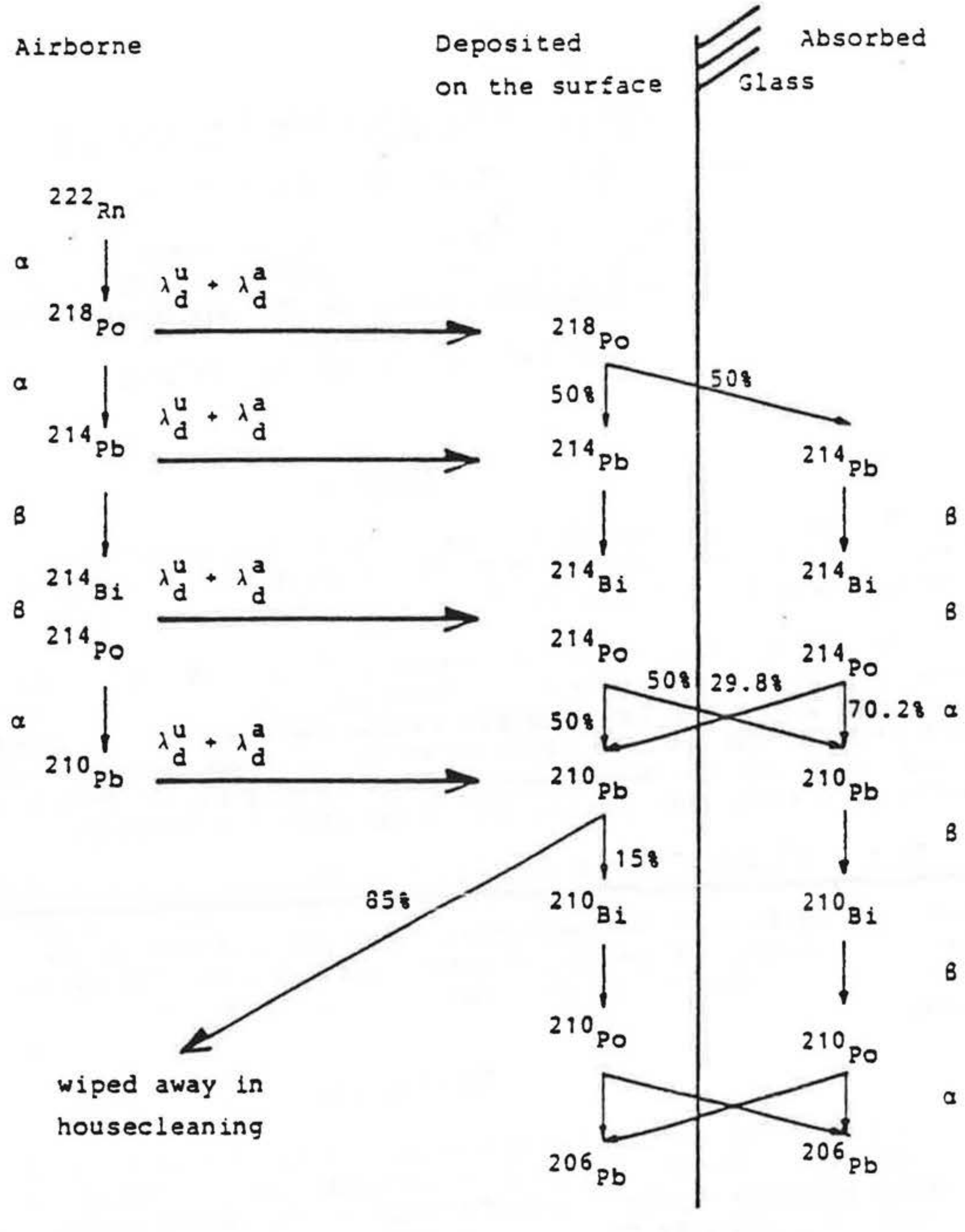


Figure 1. Decay-product deposition and absorption mechanisms and associated transfer probabilities.
λ_d^u is the deposition constant of the unattached decay products and λ_d^a is the deposition constant of the attached decay products.

DEPTH DISTRIBUTION OF Pb-214 AND Pb-210

The theory of Lindhard (3) provides a framework to determine the range of low energy heavy ions in amorphous media. Two recoil nuclei have to be considered, Pb-214 with a recoil energy of 112 keV and Pb-210 with a recoil energy of 146 keV. The details of the calculation are beyond the scope of this paper. They are published in dutch by Landsheere (4). A description in english is available on request.

The depth distributions of Pb-214 and Pb-210 are shown in figure 2. The full line and the broken line are calculated from Pb-214 and Pb-210 nuclei deposited on the surface of vitreous glass and recoiling into the glass.

The dot and dash line is the depth distribution of Pb-210 from Po-214 absorbed in the glass. The diffusion of the radon decay products in glass is negligable so that Pb-214 and Po-214 have the same distribution just as Pb-210 and Po-210. The depth distribution of Po-210 will always be a mixture of the two Pb-210 lines. The contribution of each line depends on the values of the transfer probabilities of the room model (see figure 2).

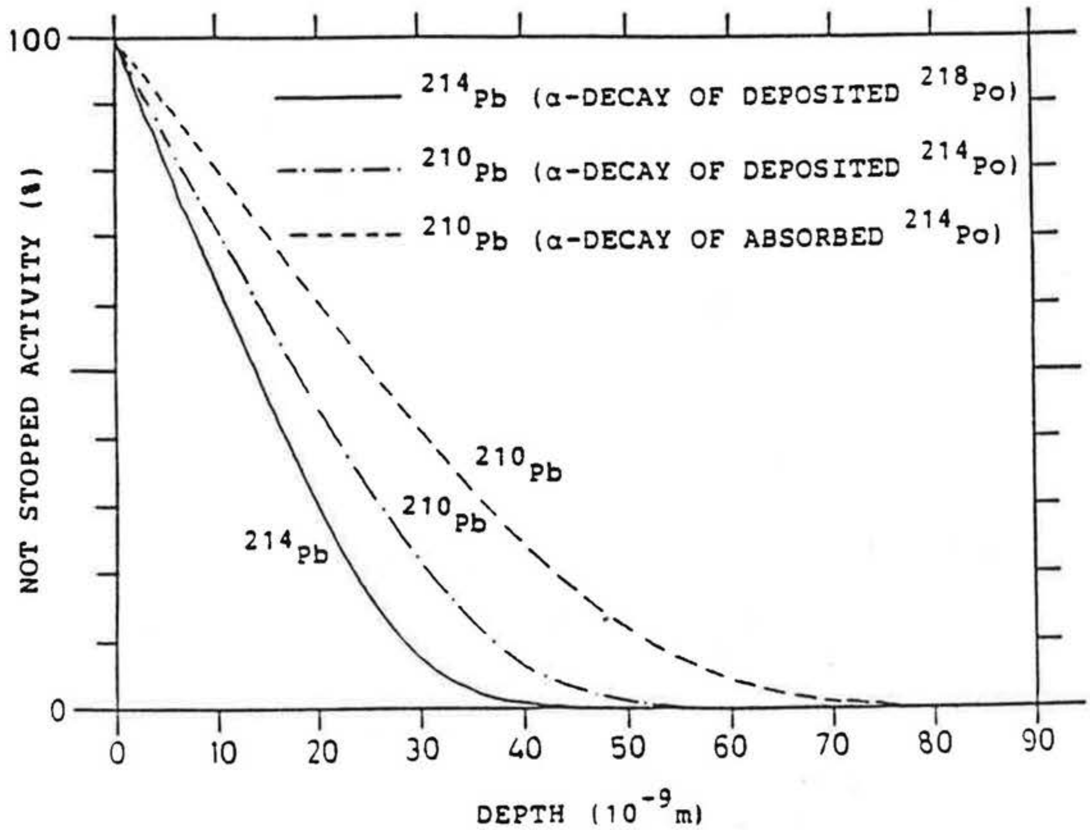


Figure 2. The penetration depth distributions of Pb-214 from decaying Po-218 deposited on the surface and of Pb-210 from deposited Po-214 and from absorbed Po-214.

The probability for recoiling Pb-210 to reappear at the surface of the glass is calculated from the depth distribution of absorbed Pb-214. The resulting probability is 29.8%.

CLEANING EFFECTS ON DEPOSITED DECAY PRODUCTS

An experimental arrangement was setup to investigate wether cleaning removes the deposited activity (see figure 3). A radon chamber of 1 m^3 was filled with radon laden air having a relative humidity of 50%. NaCl aerosol was produced with an atomiser and supplied to the chamber at least 4 hours before performing a measurement.

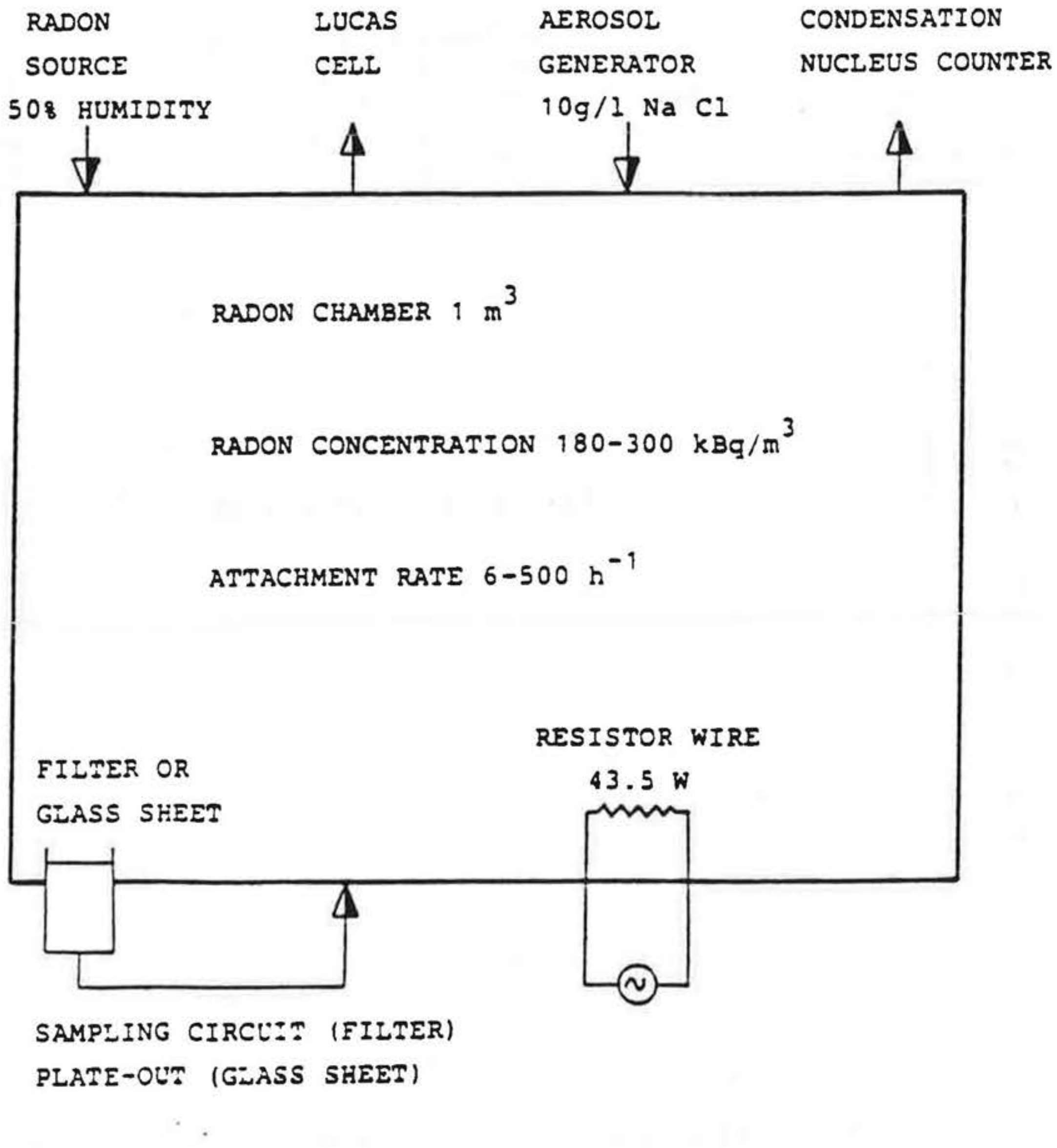


Figure 3. Experimental setup.

The aerosol concentration was measured with a condensation nucleus counter. Turbulence was standardised with a resistor wire dissipating continuously 43.5 W in the radon chamber. A glass sheet was exposed until steady state activities for the shortlived decay products were reached. The Po-218 and Po-214 α-activity of the glass sheet was measured outside the radon chamber for 20 min. Then the glass was cleaned with a cloth containing alcohol and the remaining Po-214 was registered.

Cleaning removes activity from the glass. The number of counts if no cleaning would have taken place was obtained from a filter measurement. The details of the procedure are given by Cornelis (5). The non-wiped fraction is shown in figure 4 as a function of the attachment rate. The indicated error is one standard deviation. The attachment rate was calculated from the particle concentration using the formula of Bricard (6). The diameter distribution was measured a few times with an electrostatic classifier. About 35% of the activity remains on the glass after cleaning. The scatter at high attachment rates is due to counting statistics caused by low plate-out. The lines are the calculated ratios of the absorbed activity to the total activity (absorbed + deposited). They are assessed from the room model using two sets of deposition constants for the unattached decay products. The dashed line was calculated with the same value for the three shortlived decay products (11 l/h, 11 l/h, 11 l/h). Recent experiments (7) indicate that the unattached deposition constant of Po-218 has a higher value than the one of Pb-214. Different values were taken to calculate the full line (11 l/h, 5.5 l/h, 5.5 l/h). A higher deposition constant for Po-218 gives less deviation between theory and experiment (see figure 4).

Cleaning the glass once doesn't remove all of the deposited activity. From the difference between the experimental and the theoretical values (see figure 4) it is concluded that about 15% of the deposited activity remains on the glass.

CALCULATION OF THE Po-210 SURFACE ACTIVITY

The fraction of the Po-210 activity remaining on vitreous glass depends on the values of the parameters of the room model. Most of the variability is due to the deposition constant of the unattached decay products and due to the attachment rate. The surface activity of Po-210 is given in table 1 assuming a radon air activity of 1 Bq/m^3 during 50 years. During this period the following conditions are assumed to be present on an average.

- Ventilation rate 1.0 l/h.
- Surface to volume ratio 3 l/m (a typical value for a furnished room).
- 15% of the deposited activity is not cleaned away.
- Deposition constant of the unattached decay products 10 l/h or 20 l/h or 30 l/h. The same value is taken for all of the decay products.
- Deposition constant of the attached decay products is 1/100 of the deposition constant of the unattached decay products.
- Attachment rate 20 l/h or 40 l/h or 100 l/h.

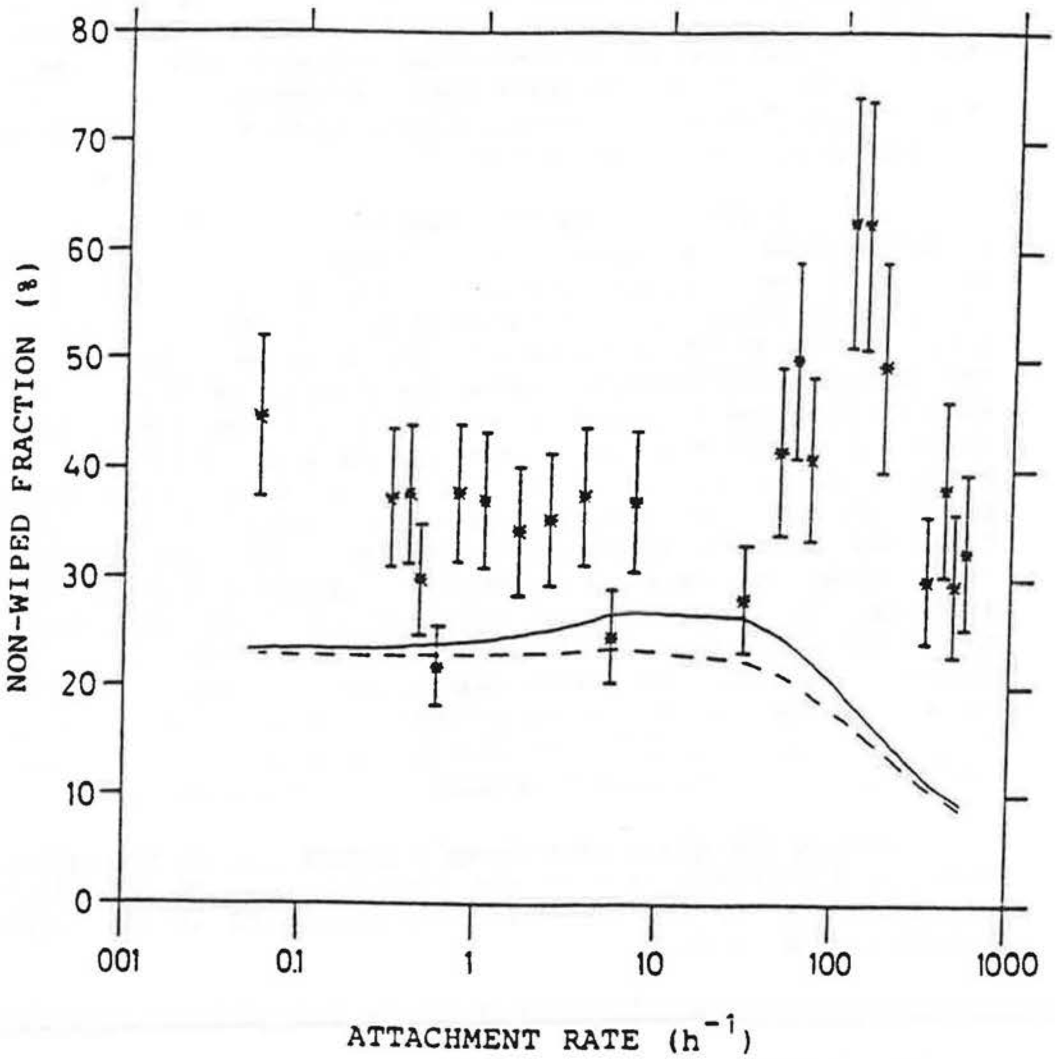


Figure 4. The remaining Po-214 activity after cleaning the glass sheet with a cloth containing alcohol versus the attachment rate. The lines are calculated from the room model using two sets of deposition constants for the unattached decay products. Only the absorbed fraction is assumed to withstand cleaning.

The surface activity of Po-210 is only 3 to 13% of the radon air activity. The attachment rate and the deposition constant are about equally important. The lower and the higher values of the attachment rate are typical for rooms without and with aerosol sources. The surface activity is about a factor of two lower if aerosol sources are present in the room. Turbulence influences the deposition constant. The presence of a convection heater near the vitreous glass, for instance, will enhance the surface deposition.

These considerations indicate that an accurate determination of the cumulated radon activity involves an estimation of the time averaged attachment rate and of the time averaged deposition constant of the unattached decay products.

TABLE 1. THE DEPOSITED AND ABSORBED SURFACE ACTIVITIES OF Po-214 AND Po-210 ASSUMING A RADON AIR CONCENTRATION OF 1 Bq/m^3 DURING 50 YEARS

X	λ_d^u	Deposited	Absorbed	Without cleaning Deposited	 Absorbed	With regular cleaning Absorbed + 15% deposited
		Po-214	Po-214	Po-210	Po-210	Po-210
1/h	1/h	Bq/m^2	Bq/m^2	Bq/m^2	Bq/m^2	Bq/m^2
20	10	0.12	0.04	0.07	0.07	0.08
20	20	0.16	0.06	0.09	0.10	0.11
20	30	0.18	0.08	0.10	0.11	0.13
40	10	0.08	0.03	0.05	0.05	0.06
40	20	0.13	0.05	0.08	0.08	0.09
40	30	0.15	0.06	0.09	0.09	0.10
100	10	0.05	0.01	0.04	0.03	0.03
100	20	0.09	0.03	0.06	0.05	0.06
100	30	0.11	0.04	0.07	0.06	0.07

DISCUSSION

The depth distributions of Pb-214 and Pb-210 in glass were calculated from recoiling surface activity and from recoiling Pb-210 already absorbed in the glass, using the theory of Lindhard (3) (see figure 2). Diffusion of the radon decay products in glass is negligable so that Pb-210 and Po-210 have the same distribution. In practice the depth distribution of Po-210 is composed of the two Pb-210 distributions. The importance of each distribution depends mainly on the aerosol and plate-out conditions in the room.

The probability for absorbed Po-214 to reappear at the surface of the glass upon α-decay is 29.8%.

The absorbed decay products are found in a thin layer of less than 100 nm, see figure 2. It should be investigated if decades of household cleaning doesn't remove this layer.

Another problem arises when the vitreous glass is not regularly cleaned. Dust will cover the glass so that a fraction of the recoil nuclei will be stopped in the dust and will be wiped away when the glass is eventually cleaned.

These considerations indicate the need for some tedious experimental work.

Experimental investigations indicate that 15% of the deposited activity remains on the surface of vitreous glass when cleaned once with a cloth containing alcohol. This may be due to radon decay products forming chemical bonds to the glass or to deposition of the decay products into microcracks present on the surface of glass.

ACKNOWLEDGMENT

This work is partly funded by the Commission of the European Communities under contract BI7*-0047-C(JR).

It is not funded by the U.S. Environmental Protection Agency and therefore the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

REFERENCES

1. Lively, R.S. and Ney, E.P. Surface radioactivity resulting from the deposition of Rn-222 daughter products. Health Phys. 52 : 411-415, 1987.

2. Samuelsson, C. Retrospective determination of radon in houses. Nature. 334 : 338-340, 1988.

3. Lindhard, J., Nielsen, V. and Scharff, M. Approximation method in classical scattering by screened coulomb fields. Mat. Fys. Medd. Dan. Vid. Selsk. 36 : 10, 1968.

4. Landsheere, C. Experimentele en theoretische studie van de fraktie van de Po-210 aktiviteit geabsorbeerd in glas. Student thesis, State Univ. Gent, Nucl. Phys. Lab., 1989.

5. Cornelis, J. Experimentele studie van de invloed van aerosolen op de in glas geabsorbeerde fractie van de Po-210 activiteit. Student thesis, State Univ. Gent, Nucl. Phys. Lab., 1990.

6. Bricard, J. Physique des aérosols II, nucléation, condensation, ions, électrisation, propriétés optiques. Report Commisariat à l'Energie Atomique, R-4831, 1977.

7. Vanmarcke, H., Landsheere, C., Van Dingenen, R. and Poffijn, A. Influence of turbulence on the deposition rate constant of the unattached radon decay products. Accepted for publication in Aer. Science and Techn. 14, 1991.

Session II:

Radon-Related Health Studies --PANEL

"Risk Communication"

AMERICAN LUNG ASSOCIATION'S RADON PUBLIC INFORMATION PROGRAM

by: Leyla Erk McCurdy
American Lung Association
1726 M Street, NW, Suite 902
Washington, DC 20036-4502

ABSTRACT

The American Lung Association (ALA), the nation's oldest voluntary health organization, is dedicated to the conquest of lung disease and the promotion of lung health. The objective of the ALA Radon Public Information Program is to reduce public exposure to elevated indoor radon levels through an implementation of grassroots-based radon public awareness campaigns. The program which is funded by a grant from the U.S. Environmental Protection Agency, was initiated in December 1989 and the first phase which includes 22 local American Lung Associations will continue until May, 1991. In September 1990, the program was expanded to 40 local ALA's, in order to implement more public information programs during National Radon Action Week, October 14-20, 1990. Activities implemented by the local ALAs include distribution of free or reduced radon kits; elementary and secondary school programs; media meetings; TV news series, talk shows, feature stories; radio PSA's and talk shows; articles and feature stories in the print media; conferences; workshops; displays at fairs and other exhibitions; distribution of radon fact sheets through libraries and utility company mailings; video distribution through video chains and libraries. The local Lung Associations also serve as local promoters for the EPA/Advertising Council Radon Public Service Announcement Campaign. This paper will describe the American Lung Association's activities in communicating the radon health risk to the public and will discuss the initial results of the program.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

AMERICAN LUNG ASSOCIATION'S RADON PUBLIC INFORMATION PROGRAM

INTRODUCTION

The American Lung Association (ALA), the nations oldest voluntary health organization, is dedicated to the conquest of lung disease and the promotion of lung health. Utilizing the scientific expertise of the American Thoracic Society, the organization's medical section, for decades ALA has been pursuing its mission of prevention and control of lung disease through education, advocacy and research.

The American Lung Association is a unique national voluntary health agency. It is one organization and many organizations at the same time. In addition to the National Association, ALA consists of a network of 131 affiliated local American Lung Associations distributed throughout the United States. With the inclusion of small branch offices, the total number of Lung Associations is 267. Each Lung Association is responsible for implementing programs in the territory they serve. This way they are able to tailor the programs for the particular needs of their community. Since the local Lung Association officials are also members of the community which they serve, they not only understand the needs of the people in their area, they also know how to communicate with them. This unique organizational structure of the American Lung Association, which makes it possible to implement programs at the grass-roots level, is one of the key factors for a successful risk communication.

RADON PUBLIC EDUCATION PROGRAM

As air pollution became recognized as a threat to lung health, ALA took a leadership role in informing the public about the adverse health effects associated with air pollution in both the outdoor and indoor environments. Since the mid 1980's, when indoor radon exposure emerged as a serious health risk issue for the general public, ALA has placed particular emphasis on developing public information materials and activities related to radon. Many of the local Lung Associations have become sources of information for their communities about radon, it's detection and reduction. In many instances the local press and the broadcast media have relied on the expertise of the local Lung Associations in communicating the radon risk to their readers and viewers.

In December 1989, ALA, with funding support from the U.S. Environmental Protection Agency (EPA), initiated a program to develop and implement a grass-roots radon public awareness campaign in order to reduce public exposure to elevated indoor radon levels. Lung Associations were requested to submit proposals for public information programs which would be most effective in their territory to alert the public to the health hazards associated with elevated indoor radon exposures and to encourage public action for testing and mitigation. 22 Lung Associations were awarded grants to implement local radon public awareness campaigns.

A list of these American Lung Associations is given in Figure I.

The geographic distribution of the States where these Lung Associations are located is shown in Figure II.

The program was initiated in December 1989 and will continue until May 1, 1991. Since the program is not completed yet, only initial results are available at this time.

Although each of the Lung Association programs are unique in their implementation, there are several common threads: Five Lung Associations are implementing school education programs. ALA of Maine and ALA of Southeastern Massachusetts have targeted high school students. Norfolk Country-Newton Lung Association (MA) and ALA of Essex County (MA) have concentrated on fifth grade students, whereas ALA of Mid-Ohio is educating seventh grade students.

ALA of Chicago (IL), ALA of Southwest Indiana and ALA of Northeast Indiana have completed very successful campaigns, where a TV-series on radon was accompanied by radon test kit distribution to the public.

Two Lung Associations, ALA of North Dakota and ALA of Philadelphia and Montgomery County (PA) have chosen to request the cooperation of the utility companies in order to reach their target groups. In these areas radon information was inserted with the monthly utility bills.

Almost all the Lung Associations have distributed radon testing kits and/or radon information pamphlets and have set up displays at fairs, exhibitions or shopping malls. They have also made presentations on radon for community groups and professional organizations. Each Lung Association has put a particular emphasis on the media component of the public information campaign. They have sent press releases and public service announcements to the media, written letters to the editors, and they have contacted their television and radio stations for possible programs on radon. As a result of these efforts many newspaper articles were printed, Lung Association spokespersons appeared on television and radio talk shows and several television stations aired radon news stories.

The Lung Associations also serve as the local promoters for the EPA - Advertising Council radon campaign which was launched in October 1989 in 29 states and later was expanded to 33 states. This is a multimedia campaign with television, radio and print public service announcements, billboards, transit cards and direct mail brochures. Lung Associations have contacted their local radio and TV stations, print media, local transit authorities and billboard companies to promote the radon public service announcements. The efforts of the Lung Associations at the local level are effective in enhancing the impact of the Advertising Council's national radon campaign.

During October 14-20, 1990 which was designated as National Radon Action Week by the U.S. Congress, the American Lung Association's radon public information program was expanded to 40 Lung Associations, with additional funding from U.S. EPA.

Figure III lists the Lung Associations which joined the ALA radon public information program during National Radon Action Week.

The geographic distribution of the states where these Lung Associations are located is shown in Figure IV.

Using National Radon Action Week as a "hook", the Lung Associations were successful in reaching the public through their local print and electronic media and through other communication channels such as radon displays at malls, fairs, and public buildings; radon education programs for community groups; elementary school programs and direct mail campaigns. Lung Associations also made radon test kits available to the public at a discounted price by working closely with radon test kit manufacturers. For example, about 15,000 radon test kits were sold just in the Philadelphia area during the month of October, with the cooperation of a local department store chain.

CONCLUSION

Initial results of the ALA Radon Public Information Program indicate that grass-roots public education is one of the crucial components for radon risk communication. A significant reduction in radon risk through increased public awareness, testing and mitigation can be achieved by the collective impact of effective programs by Federal and State Agencies, participation by the scientific community and a responsive radon testing and mitigation industry in addition to local public education programs of the type implemented by the American Lung Association.

ALA of Atlanta

ALA of Chicago

ALA of Idaho

ALA of Southwest Indiana

ALA of Northeast Indiana

ALA of Iowa

ALA of Kansas

ALA of Maine

ALA of Essex County, Massachusetts

Norfolk County-Newton Lung Association, Massachusetts

ALA of Southeastern Massachusetts

ALA of Southeast Michigan

ALA of Michigan

ALA of Hennepin County, Minnesota

ALA of Mid-Ohio

ALA of Montana

ALA of North Dakota

ALA of Delaware and Chester Counties, Pennsylvania

ALA of Lancaster and Berks Counties, PA

ALA of Philadelphia and Montgomery Counties, Pennsylvania

ALA of Tennessee

ALA of Virginia

FIGURE I: American Lung Associations (ALA) participating in the Radon Public Information Program

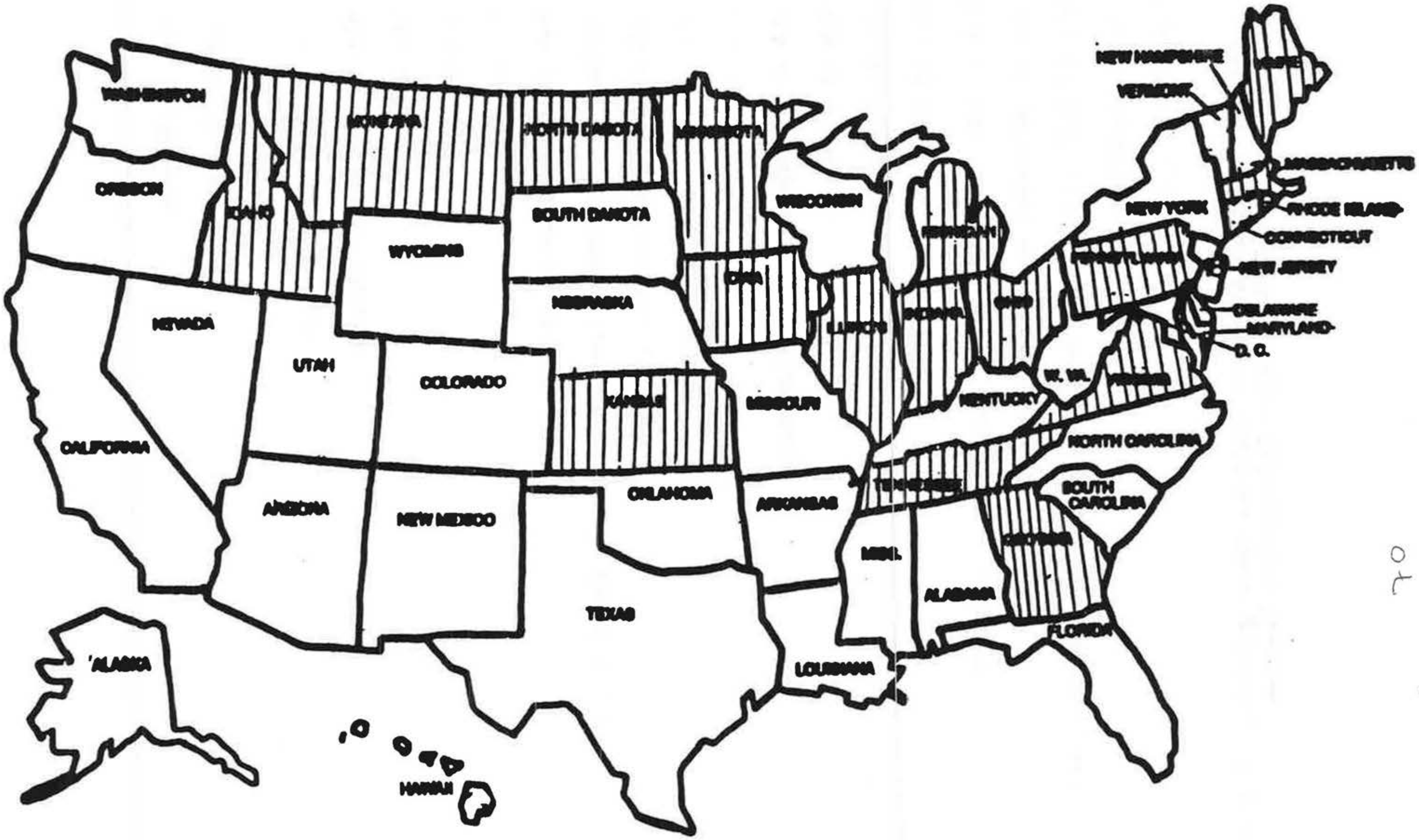


FIGURE II: States where ALAs participating in the Radon Public Information Program are located

ALA of Arkansas

ALA of the Valley Lode Counties, CA

ALA of Los Angeles County, CA

ALA of Delaware

ALA of Illinois

ALA of Central Illinois

ALA of North Central Illinois

ALA of Western Massachusetts

ALA of Minnesota

ALA of Eastern Missouri

ALA of Western New York

ALA of New York State

ALA of Green Country Oklahoma

ALA of Central Pennsylvania

The Rhode Island Lung Association

ALA of Virginia - Blue Ridge Region

ALA of West Virginia

FIGURE III: American Lung Associations (ALA) which joined the Radon Public Information Program during Radon Action Week

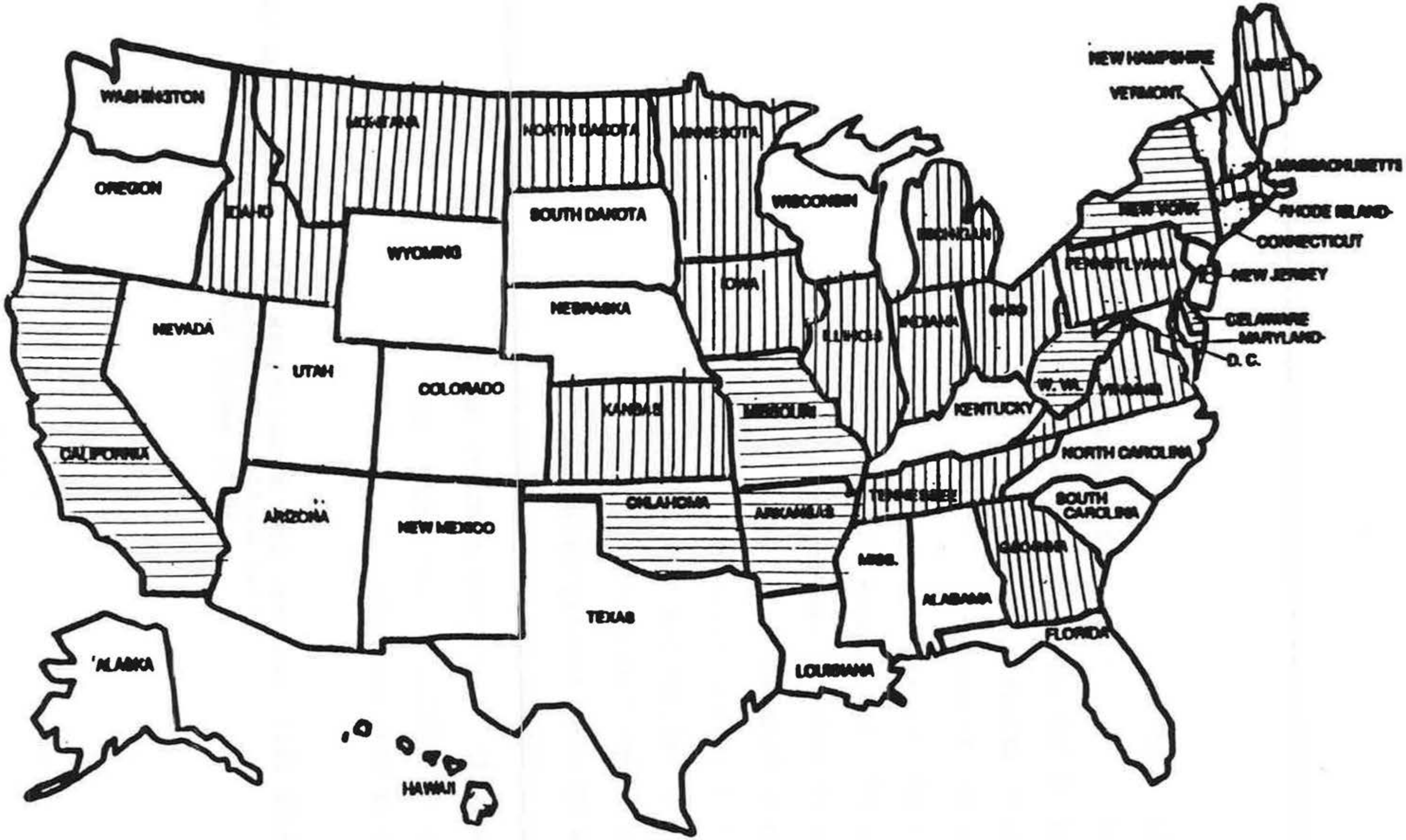


FIGURE IV: States where ALAs implementing Radon Action Week Activities are located

DEVELOPING A COMMUNITY RADON OUTREACH PROGRAM: A MODEL FOR STATEWIDE IMPLEMENTATION

by: M. Jeana Phelps, M.Ed., RT(R)
Radon Program, Radiation Control Branch
Division of Community Safety
Kentucky Cabinet for Human Resources
Frankfort, Kentucky 40621

ABSTRACT

Apathy, lack of consumer interest or urgency to test for radon is one of the most serious public health challenges facing the U.S. Environmental Protection Agency and State agencies.

This paper presents a model approach to overcoming public apathy through a community based radon outreach program. The model is based on a community network established in Western Kentucky and two others under development in Jefferson and Fayette Counties. The model includes community assessment methods for identifying key volunteers, local radon concerns, and availability of resources. It also discusses the initiation and coordination of a successful implementation. The paper serves as introductory guidance for state agencies wanting to enlist community support in promoting radon testing of all schools and buildings and follow-up actions to reduce elevated levels.

*In this paper the term group will be used to refer to organizations, associations, or agencies.

INTRODUCTION

Research released by the U.S. Environmental Protection Agency indicates that homeowners do not over-react or panic after receiving information on radon (2,3). Rather, there is a great apathy about radon as evidenced by the small percentage (5% estimated) of homes that have been tested nationwide. Of the five percent who have tested, many do not mitigate (2). Only seven percent of those with results between 4-20 pCi/l had their homes mitigated with a retest confirming success (2).

Consumer apathy in regard to radon indicates that the risks associated with radon are either not being properly communicated or the risk message is not understood. Risk communication studies indicate that consumer apathy results from a combination of these factors; use of ineffective communication media and lack of consumer internalization and adoption of the message (2,3).

Focus testing of the radon message on randomly selected populations, indicates that the communicated message must be prescriptive, personal, and simple (2,3) (Table 1).

TABLE 1: KEYS TO EFFECTIVE RADON COMMUNICATION

- Make message prescriptive rather than informative.
- Eliminate unnecessary information.
- Simplify testing and mitigation guidelines.
- Personalize radon risks.
- Overcome denial of health risks by comparing radon risks to other common risks.
- Discuss risks to special populations (smokers and children).
- Emphasize low cost, easy testing and availability of proven effective mitigation methods.

A community outreach approach allows for specific targeting of a message to the audience, making the message more relevant to those hearing it (2,3).

Complex messages such as those dealing with radon health risk can be more effectively conveyed through personal contact or through a respected community leader who also brings a sense of legitimacy to the message (2,3).

In the Iowa Radon Public Awareness Survey (1990) of 588 randomly selected households, most respondents interviewed (88.6%) had heard about radon and provided correct responses to a number of questions designed to assess their knowledge about radon. However, the results indicated that the public may know about radon, but they do not believe they know very much. Only sixty-nine people (11.7%) felt they were fairly or very knowledgeable about radon. Almost two-thirds (65.6%) indicated that they do not know much about radon. These findings further reinforce the need to communicate radon health risk to the public.

The Maryland Radon Risk Communication Research Study (1988) found the greatest public change with respect to radon awareness, knowledge, attitudes, and testing behavior occurred when people were exposed to a combination of radon information sources; e.g., news media (national and local stations), unsolicited mailings, and community outreach activities. The use of informal communication channels appeared to be an important element in explaining risk (3).

The importance of community outreach in motivating the public to change their behavior is also well illustrated in the efforts of the American Lung Association (anti-smoking), National Highway Traffic Safety Administration (seat-belt restraints), and the National Cancer Institute (early diagnosis through self examinations; i.e., skin and breast). From these examples, it becomes evident that community "grassroots" advocacy or action groups capable of networking at the national, state, and local level are essential in influencing consumer attitudes and behavior in regard to testing for radon and mitigating.

OVERVIEW OF PROGRAM DEVELOPMENT

The Kentucky Radon Outreach Program began about 1985-1986, in response to telephone inquiries from the public. With the release of the 1987-1988, statewide residential radon survey, outreach activities were expanded to include radon public awareness programs, a three day radon education program, and dissemination of the U.S. EPA's radon literature. These early activities were usually initiated as a result of public need or request.

Today, the Kentucky Radon Outreach Program consists of a multitude of diverse and dynamic activities. Instead of waiting to respond, or be reactive, the outreach program takes a controlled active approach to disseminating the radon message. By networking with groups, the radon program is able to extend its limited staff and resources across the state.

The radon outreach program is guided by three basic attitudes. These being:

- Recognize every person (contact/telephone inquiry) as a potential public communicator about radon.
- Accept people where you find them and start from there to build a working relationship.
- Make use of most peoples' willingness to help.

These are realistic attitudes, since anyone who attempts to solicit assistance from public and private groups, will soon learn that radon is not a "priority" for everyone. To build effective liaisons, one must be flexible and willing to negotiate. This is especially important when attempting to establish outreach activities with school officials, home builders, real estate agents, and others who are often on the front "firing line" in regard to radon issues.

Community outreach activities organized through groups, by nature, generally reach a specific target audience and have definite measurable objectives (Table 2). Activities for such groups are often time and content limited; i.e., a radon awareness program, one-time literature dissemination, etc. Although community outreach through specific groups is critical to taking the radon message to the public, these groups do not have the individual capability of addressing community radon issues. Such issues which encompass schools, daycares, real estate, new construction, testing availability and a myriad of others, must involve community leaders and citizens. To bridge this gap, the radon community action (advisory) committee concept was established. These committees, consisting of community leaders, can with assistance from the state radon agency, coordinate a community-wide response to radon. Therefore, the Kentucky Radon Outreach model is based on both group specific activities and community action committee initiatives.

COMMUNITY OUTREACH - GROUP SPECIFIC

Getting started was simple and consisted of four major steps:

1. Determining purpose of radon outreach
2. Listing objectives and sub-tasks
3. Implementing action (work plan)
4. Tracking, analyzing, and evaluating progress

The specific activities involved in each of the major steps are presented in Table 2. The following represents experiences and insights gained through this process.

LESSONS LEARNED-GROUP SPECIFIC OUTREACH

The scope of any state's radon outreach program is ultimately dependent upon the amount of time radon staff can devote to outreach. Staff time is probably more important than project funding or resources. Staff time is necessary for making the initial group contact, negotiating the plan of work (outreach program), and providing ongoing attention and support to "keep the program on track". Radon staff must also take the lead in evaluating outreach effectiveness and apply this information to future program development.

Experience has shown that more staff time is required when working with purely volunteer groups as compared to groups with salaried staff. Commitment of staff time to a specific group outreach program seemed to be reduced once the initial meeting was conducted and a plan of work (outreach activities) agreed upon. The plan of work, which lists the objectives and sub-tasks, serves as a very important blueprint for periodic tracking and evaluation. (Appendix A)

Step 1: Determine Purpose

The purpose of the radon outreach program is to promote radon awareness activities that provide citizen's of the Commonwealth with information about radon, its risks, testing and mitigation strategies to the extent that they can make informed decisions about radon in regard to their health and well being.

Step 2: List Objectives/Sub-Tasks to reach goals

Considerations
- Budget
- Staff
- Other on-going public information activities
- Timelines (Flexible/Negoitable)

1.1 **Establish community outreach programs through intermediaries (organizations/associations) who impact special interest groups**
- Identify the organizations/associations
- Identify Key Contacts
- Prepare for first meeting
  -know the organizations goals, mission, philosophy, etc.
  -know if any radon networking has occurred at the national level. ie: American Medical Associations position on radon, National PTA resolutions, etc.
  -Find out, if possible, what interest they may have in radon.
  -Be very clear about the desired assistance being sought from the organization. (ideal work plan)
- Telephone the contact and arrange for a meeting.
- Prepare a meeting agenda.
- Meet with contact, introduce the radon program and networking expectations. Negotiate, revise plan. Set timelines. (Provide contact with literature)
- Follow-up meeting with thank you letter and a revised plan of work.
- Implement plan of work. (Provide on-going support, assistance, reminders, etc.)

1.2 **Establish community radon action committees in designated high potential radon regions or communities**
- Determine regions (in Kentucky, the four regions with the highest incidence of elevated radon levels were selected Jefferson, Warren, Fayette, Somerset).
- Identify key contacts representing the diverse sectors of the community to serve. (Look to established radon outreach groups)
- Solicit a key contact to serve as committee chairperson.
- Assist chairperson in organizing committee, selecting members, etc.
- Provide committee with support and resources needed to identify and respond to their community's needs. (Radon staff responsible for providing information about state)

Step 3: Establish tracking and evaluation measures

Considerations
- Plan of work should serve as tracking guide
- Prepare a written summary of progress

- Detrmine timeline intervals for tracking progress and evaluation of the program. Do so with input from organization contact. (Review plan on a pre-determined schedule)
  -Tracking progress provides for the quick identification and correction of problems that might otherwise delay progress.

Table 2: STEPS IN ESTABLISHING GROUP SPECIFIC RADON OUTREACH PROGRAMS

IMPLEMENTING GROUP SPECIFIC OUTREACH

After identifying target groups, the next task is to identify key contacts. State radon staff should find out as much about the group as possible before preparing a plan of work and making contact. Such information includes organizational structure, mission and goals, and how radon intersects with these. These facts should be used to determine the best approach and message to use when communicating with the group. The first meeting is crucial; be prepared to take the following items:

- Meeting agenda-outlining goals/activities between state agency and group (tentative work plan)
- Fact sheet about radon and the state radon program.
- State residential survey findings.
- Resource pamphlets
- Group specific information (Radon in Schools Pamphlet, etc).

While preparing the preliminary plan of work, list sub-tasks, and set timelines with measurable milestones. Also, determine who will be responsible for the activities listed. To keep radon outreach programs on track, the state radon staff must serve as the "spark plug" taking the initiative to provide reminders to group contacts as needed. Staff also must provide support, assistance, and always a THANK YOU.

Evaluation of each project includes a periodic status report or summary, and a final overview upon completion of the project, with a copy going to all participants. A post-project group meeting allows review and provides an opportunity to discuss future outreach activities.

A matrix tracking schedule is being considered as one way to keep all staff informed about the progress of each outreach program and to serve as a reminder to take action. (Refer to Appendix A)

BUDGET

Radon outreach programs require sufficient funding for staff, and resources; such as printing of U.S. EPA pamphlets/handouts, travel, postage, and long distance telephone calls. Outreach requires dedicated staff time and unless this is available, effective outreach programs may not evolve.

In Kentucky, outreach activities are being funded by the U.S. EPA State Indoor Radon Grant and state match under the public information category.

RESULTS

From 1989 to the present, the Kentucky Radon Program has established many contacts that have resulted in community radon outreach programs. Some of these are highlighted in Appendix D. Examples of specific group outreach plans are included as Appendix E (Rural Electric Cooperative Outreach) and Appendix F (Jefferson County School District/PTA Outreach).

UNRESOLVED ISSUES

The unresolved issues that seem to be most important relate to the following:

- How to measure outreach program effectiveness and how to apply this knowledge to future program development.
- How to determine if programs are cost effective.
- How to negotiate and network with groups who refuse to acknowledge radon as a serious health threat.

The most important unresolved issue recognized was the actual limitations of group specific radon outreach programs to be a mobilizing force within local regions or communities. This issue is being met by the second objective of the Kentucky Outreach Model; that being, to establish community radon action committees in designated high potential radon regions or communities.

INTRODUCTION-COMMUNITY RADON ACTION COMMITTEE

Community radon action committees are a part of the state radon program's outreach plan. Community radon action committees consist of members who can identify with the diverse radon issues facing the community, whereas, group specific radon outreach programs are more concerned with radon issues facing its membership. Active members of "group" specific outreach programs are valuable resources, as are elected leaders, public health officials, and other "very visible" community representatives. These individuals should be invited to serve on radon action committees.

GETTING STARTED-ORGANIZING COMMUNITY RADON ACTION COMMITTEES

A decision was made to organize four community radon action committees during 1990-1991. Because many group specific radon awareness activities were already being conducted in potentially high radon areas of the state, these areas became the ideal setting to locate action committees.

Once the state locations were selected, radon staff began to identify an organization or individual to take charge of calling a committee together. This responsibility fits best with an agency that is already empowered to respond to the health and well being of the community.

Possible committee organizers may be identified from such groups as local health, American Lung, American Cancer, extension service and rural electric cooperatives.

The Warren County Radon Action Committee was organized by a home economics extension agent from the Warren County Cooperative Extension office. The Louisville-Jefferson County committee was organized by the Deputy Director of Environmental Health, Louisville-Jefferson County Health Department. The committees' success in addressing radon will not only be contingent upon the commitment of the chairperson and state staff, but also on the strength of the selected members and their community visibility.

DEVELOPING A COMMITTEE PROPOSAL

The radon program staff and selected chairperson usually work together to draft an initial committee proposal (Table 4), select committee members, and plan the first meeting (Refer to committee letter, Appendix G).

The sample outline found in Table 2 can be used as a planning guide when organizing a radon action committee. In Warren County, faculty from the Center for Mathematics, Science, and Environmental Education, Western Kentucky University, assisted the county agent in planning the meeting. The radon staff supplied state survey data, technical resource manuals, and evidence of local radon issues reported to the state office. Since not all committee members begin with a common background in radon and related issues, it is important to provide an introduction to radon at the first meeting. Once the committee is organized and begins to identify and address community radon issues, the chairpersons' role becomes critical to maintaining committee momentum in meeting the stated goals. As in the Warren County committee, the chairperson has appointed sub-committees to complete specific assignments and report back to the group. Appendix G illustrates a meeting follow-up and reminder letter.

The outline in Table 4, provides details about the Louisville-Jefferson County (task force) community action committee.

LESSONS LEARNED

Organizing and implementing community radon action committees requires a time commitment and seems to naturally follow group specific outreach awareness activities. If a committee is formed in an area where there has been very little radon awareness; then, this becomes an initial goal of the committee.

Community Radon Action Committees cannot take the place of state enforced radon regulations (which Kentucky currently does not have); however, these committees can serve as an impetus to the development of such regulations. Also, since these committees consist of community leaders, they may serve as allies in demanding state action regarding radon.

LOUISVILLE-JEFFERSON COUNTY
RADON TASK FORCE
A LOCAL INITIATIVE PROPOSAL

LOCAL ACTIVITY PROPOSAL

If the issues surrounding radon are to be addressed in an orderly and consistent manner, it is important that Louisville and Jefferson County develop a local mechanism to plot a course which will deal with the issues before they become emotionally charged. A time limited task force similar to the AIDS task force is proposed for this purpose.

The mission of the task force would be to evaluate and make recommendations for action in each of the following areas:

1. Identify of the extent of problem within Louisville and Jefferson County to include a review of public education efforts and the need for additional education/awareness.

2. Review of current processes for testing and mitigation. Such review would include a determination of the need for professional certification of persons conducting testing and mitigating.

3. Establish procedures necessary for the prevention of radon problems in new construction.

4. Determine policy for handling of test results. This includes public dissemination of information that indicates high potential areas and disclosure of testing information at the time of property sale or transfer.

In order to get maximum value from the task force, broad-based representation is necessary. Representation from the following agencies/groups is proposed:

County Government
City Government
Health Department
Parent Teacher Associations
Boards of Education
American Lung Association
Realtors Association
Homebuilders Association
Regional Radon Training Center
Plumbers Association
Am. Industrial Hygiene Assoc.
Cooperative Extension Service
Mortgage Lenders Association
Ky. Hospital Association
Jeff. Co. Medical Society
American Cancer Network
Ky. Radon Association
Louisville Bar Association
Louisville Gas & Electric

Task force members would be invited by the Director of the Jefferson County Department of Health. Staff support for the task force would be provided by the Health Department, the Radiation Control Branch and solicited from other participating groups. In January 1991, the Radiation Control Branch (Radon Program) is sponsoring a radon awareness training session in Jefferson County. Ideally, the task force could be appointed and have had at least one organizational meeting prior to that training session.

It is anticipated that the task force would function for approximately 18 months. At the termination of the project, a final report would be prepared and submitted to the County Judge, Mayor and Board of Health.

Table 4
Louisville Jefferson County Task Force

SUMMARY

Taking action to test and mitigate structures becomes a complex issue when the structures are schools, public/state buildings, daycares, places of employment, property for sale, water sources, etc. When radon is present in these structures, the lines of responsibility sometimes become obscure. Radon, then becomes a community problem not unlike AIDS, Drugs, etc., that must be faced by those involved in the community; its' citizens, and those empowered with public policy decision making. In Kentucky, the use of community outreach programs and community action committees has proven to be an invaluable resource in taking the radon message to citizens. These programs have been, and will continue to be, used, developed, and refined in order to meet the Commonwealths' need for radon information and technical assistance.

ACKNOWLEDGEMENTS

The author would like to acknowledge and thank the many people in Warren, Jefferson and Fayette counties who have accepted the challenges of radon risk communication, especially Radon Chairperson, Clark Bledsoe, Deputy Director, Louisville-Jefferson County Health Department and Radon Chairperson, Sandra Proffitt, Home Economics Extension Agent, Warren County Extension Service. Special thanks to Tamara Guy for word processing support on this paper.

Without their support, assistance and networking, the substance of this paper would not be a reality. Also many thanks to the Kentucky Radiation Control Branch for allowing me the freedom to take a non-traditional "radiation agency" approach to the radon program and to USPEA Region IV and Headquarters staff for always listening to my dreams. Also without funding from the USEPA State Indoor Radon Grant, many of these activities would not be a reality.

REFERENCES

1. Johnson, Raymond H. - Radon Risk Assessment and Risk Communication The Radon Industry Review, Vol. 2, No. 10 November 1990

2. U.S. Environmental Protection Agency Office of Radiation Programs, Radon Division Technical Support Document for the 1990 Citizen's Guide to Radon (Draft) Washington, D.C. 1990

3. U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, Program; Evaluation Division. Region 3/ OPPE/ State of Maryland Radon Risk Communication Project: An Evaluation of Radon Risk Communication Approaches. Washington, D.C. - November 1988

4. U.S. Department of Health and Human Services. Making Health Communication Programs Work; A Planner's Guide. NIH Publication No. 89-1493, April 1989

5. Conrad, William R. Jr. and William E. Glenn. The Effective Voluntary Board of Directors. Swallow Press, Athens, Ohio 1983

6. Radon Public Awareness in Iowa, Report on 1990 Survey. Conducted by the Iowa Department of Public Health.

7. Extension Committee on Organization and Policy/Community Resource Development - Public Affairs Subcommittee: National Extension Task Force on Community Leadership. Community Leadership Development, Implications for Extension. The Northeast Regional Center for Rural Development, University Park, PA.

Appendix A

1990 Plan of Work
Extension Service and Kentucky Radon Program

Timeline	Person	Activity/Task	Status (* Pending)
Oct/Nov 1990	Jeana Rick	Starter-Kit Radon literature to all Districts	Accomplished
Dec 5, 1990	Jeana	Present overview of Radon Program to Area Directors, UK-Good Bain	Accomplished
Dec 1990	Jeana Dwight	Prepare innovative EPA Grant proposal to provide training to 4-H Youth Leaders and members. Grant year Nov 91 - Oct 92	Draft prepared submitted to EPA by Dec 12th deadline. *Award notification in Spring 1991.
ASAP	Jeana	Application to Velma Koostra for State Homemaker's meeting - Radon Presentation	Accomplished Scheduled to speak May 17, 1991 *Need to work with Sandra Proffitt on Presentation.
ASAP	Jeana	Contact Joan Martin, WKU Center for Math, Science, Env. Edu. regarding development of a Radon Leader's Guide for use by cooperative extension agents.	EPA ok'd use of SIRG grant funds to be transferred from Amer. Lung Project for use in Project. Talked with Joan 1-7-91 and will follow-up with letter of Proposal.
	Jeana, Joan, Sue Bill, others?	*Will need to review project proposal and then to schedule a project org. meeting.	
Spring 91	Jeana	Provide radon training video to UK Dept. of Ag Communications and to the 14 CO-OP Ext. Districts.	*SIRG funds to pay for video
Ongoing	Jeana	Radon Awareness through local Agriculture radio broadcasts.	*Explore further with Sue and Bill
March-April	Jeana & designated KET Staff	Determine feasibility of utilizing cooperative extension agents as on-site school facilities during KET-radon statewide broadcast.	*As we develop KET production
Ongoing	Jeana	Renew radon literature to districts	Upon request
Ongoing	Jeana/Regional Radon Training Center	Provide comprehensive-technical radon training to agents.	*Need to explore waiving tuition with Ellen Korn.

Appendix B

LOCAL HEALTH AGENCIES
CHAMBER OF COMMERCE
REAL ESTATE AGENTS/BROKERS
STATE REAL ESTATE COMMISSION
CHURCH GROUPS
PHYSICIANS > HEALTH PROVIDERS
BANKERS
BOY-GIRL SCOUTS
STATE & PRIVATE SCHOOL OFFICIALS
CANCER SOCIETY
HOSPITAL VOLUNTEER GROUPS
FRATERNAL & CIVIC ORGANICATIONS
LOCAL EMPLOYERS
BUILDING INSPECTORS/MANAGERS
PARENT-TEACHERS ASSOCIATION
COUNTY EXTENTION AGENTS
HOME BUILDERS
PLUMBING AND AIR CONDITIONING
EDUCATOR'S
ELECTED OFFICIALS
LIBRARY RESOURCES
HABITAT FOR HUMANITY
AMERICAN LUNG
HEALTH ASSOCIATIONS & AUXILLARIES
DAYCARE OPERATORS
HOMEMAKERS
NEIGHBORHOOD ASSOCIATIONS

APPENDIX B. SUGGESTED CONTACTS FOR COMMUNITY OUTREACH

Appendix C

TIPS FOR SELECTING ORGANIZATIONS, AGENCIES OR ASSOCIATIONS FOR RADON OUTREACH

1. Choose organizations, agencies, or individuals who can reach and influence the desired target audience.
2. Involve representatives from the organizations early in the planning process.
3. Set realistic timelines and deadlines.
4. Allow organizations to personalize and adopt the presented work plan.
5. Ask what they need; i.e., training, resources, support, etc.
6. Help them take responsibility for their activities - but don't do it for them.
7. Provide them with additional local, regional, and national contacts or linkages that they will perceive as valuable for their ongoing activities.
8. Provide them with information about the radon program and other information, in ready to use form.
9. Don't overwhelm them with information, give clear simple messages.
10. Track progress and make adjustments as necessary.
11. Provide support, thank you's, and other forms of recognition.
12. Provide written follow-up after the first planning meeting to document tracking and evaluation progress.

Adapted from "Steps for Involving Intermediaries in Your Program." Making Health Communication Programs Work. U.S. Department of Health and Human Services, Public Health Service, National Institute of Health and Office of Cancer Communications, National Cancer Institute, NIH Publications No. 89-1493, Bethesda, MA 1989.

Appendix D

KENTUCKY COMMUNITY RADON OUTREACH PROGRAM
AN OVERVIEW (1990-1991)

Organization/Association	Outreach Activities
Kentucky Library Association	• "Starter" Package of Radon Literature sent to 120 public/private libraries. (1991)
Housing Authority of Kentucky	• Radon Awareness Program at Fall State Meeting. (1990)
American Lung Association of Ky	• Endorse radon program activities. • Provide radon literature through agency networks. • Assist Salt-River Rural Electric Co-Op in radon testing campaign. (1991-1992)
Local Health Departments	• Distribute radon literature. • Respond to telephone inquiries. • Attend radon training.
Home Builders Association of Ky	• Assign code committee to review EPA's pre-construction radon resistant building techniques. • Radon article in state journal. (1991) • Radon booth at builder's annual meeting. (1990-1991) • Sponsor radon awareness program at State meeting. (1991)
Jefferson County Medical Society	• Publish radon article in Society Journal. (1990) • Plan to provide a radon "starter kit" to all doctors to place in reception room. (1991-1992 - statewide) • Endorse radon program initiatives. • Network to Auxillary and to other county associations.
Kentucky Medical Association	• Endorse the radon program initiatives by resolution. (1989-1990)
University of Kentucky School of Engineering	• Sponsor radon awareness in annual continuing education. (1990)

*(Starter package includes 25 Citizen's Guides to Radon, What it is and what to do about it (1986), Radon Reduction Methods, A Homeowner's Guide (Third Edition). U.S. EPA, RCP and RMP List for the State, State Survey Map.)

Appendix D

Organizations/Association	Outreach Activities
Kentucky Kiwanis	• Radon awareness programs - Frankfort and Louisville. (1991)
Salt River Rural Electric	• Publish radon article in magazine. • Sponsor radon awareness programs for all employees through safety program. (1990) • Provide radon awareness booth at summer festival in Bardstown. (1990) • Provide radon literature in display rack. (On-going) • Sponsor radon testing service for Co-op members. (On-going)
Rural Electric Co-Op Association	• Sponsor radon awareness at statewide member service meeting. • Publish radon article in statewide newletter.
Ky Home Mortgage Association	• Sponsor radon awareness for association members.
Ky Parent Teachers Association	• Endorse Ky Radon Program initiatives. • Publish radon information in Quarterly Association Bulletin. • Sponsor radon awareness program at State Convention and Spring Leader Training. • Sponsor PTA State and National radon resolution.
Ky Cooperative Extension Service	• Provide radon literature "starter kit' to 120 service areas for distribution. • Sponsor radon awareness for district managers. • Support networking at the local level. • Plan to educate all 4-H Youth.
Jefferson County Parent Teachers Association	• Coordinate in conjunction with District Superintendents' Office, a radon awareness program for all Principals. Individual schools will then be empowered to host radon awareness program for parents and staff.
District 3 PTA (Warren County)	• Sponsor radon awareness at Fall Planning Conference. (1990)

Appendix D

Organizations/Association	Outreach Activities
Louisville Gas/Electric	• Utility Bill Radon Insert sent to 317,000 residents, businesses.(1990)
Kentucky Certified Radiation Operators	• Radon articles about testing and mitigation published in statewide radiation newsletter. Sent to 5,000 radiation certified operators.
Ky Real Estate Commission	• Provide fifteen radon awareness programs statewide to licensees of the commission. (SIRG Grant, 1990)
Ky Vocational Education	• Sponsor three day radon training for building trade, construction faculty. (SIRG Grant, 1990) • Faculty to infuse radon information into existing curriculum. (On-going)

SUGGESTIONS FOR RURAL ELECTRIC COOPERATIVE COMMUNITY AWARENESS

1. Place radon literature in lobby display racks

   A Citizen's Gude to Radon (OPA-86-004, August 1986)
   Radon Reduction Methods, A Homeowner's Guide (RD-681, July 1989)
   List of EPA proficient testers (RMP)
   List of EPA proficient mitigators (RCP)
   (All above are available upon request from radon program)

2. Public radon information in utility bill insert

   Refer to sample published by Louisville Gas & Electric Company (January 1990)

3. Publish radon article in rural electric magazine

4. Host a radon awareness education program

   Invite members, employees, and the public to attend a radon program (speakers provided by radon program)

   Invite local school officials to provide radon test data about school testing

5. Consider providing radon test kits to service members

   Enter into an agreement with an EPA approved radon laboratory. Cooperative provides order forms to members. Member orders kit directly from company. Member receives test results directly from the company. Cooperative receives some percentage of cost for each kit. (refer to handout)

6. Consider conducting radon tests on any home receiving an energy efficient 'tight home' installation from the cooperative

   Explore legal liability
   Decide on approach
   Develop a plan of action to protect the cooperative and citizen(s).

7. Join forces with other community leaders to host a community radon testing campaign

Local Medical Society	Cooperative Extension Agents (Ag & Home Ec)
Lung Association	Local Health Department
Daycare Operators	Local Government Officials
PTA/Schools	Cancer Network Volunteers

COOPERATIVE EXTENSION TO COMMUNITY
RADON COMMUNICATION OUTREACH PROGRAM

Audience	Type of Communication	Message	Method
Co-op Extention Agents Home Ecomonics, Agriculture, Youth	Technical-Informational Resource-Supportive Motivational	- Radon Update - Testing Protocols - Mitigation techniques - Resources available - Encourage all agents to test their homes and to take action if elevated levels are found.	- Distribute Radon literature to all agents through UK Communication Channels - Invite all agents to attend one of the four regional radon workshops in Jan-Feb 1991
Citizens in Home Community	Informational (Awareness) Technical (Advisor or Referral) Motivational	- Radon threat in Local Community - Facts about radon - How to test for radon - How to Mitigate a home to reduce radon levels - Who is qualified to test and/or mitigate - Which tests are EPA Approved - Encourage all citizens to test their homes for radon and to take action if elevated levels are found.	- Establish support Network between individual agents and radon program staff. - Conduct Community radon awareness workshops - Speak at Civic association meetings - Provide radon literature in Extension Office. - Host local radon testing campaigns - Host radon mitigation demonstration project

Audience	Type of Communication	Message	Method
Homemakers Clubs Members	Informational (Awareness) Motivational	- Radon threat in local community - Facts about radon - How to test for radon - How to mitigate a home to reduce radon levels. - Who is qualified to test and/or mitigate - Which tests are EPA approved - Encourage all home-makers to test their homes for radon and to take action if elevated levels are found.	- Host radon awareness program at local homemakers clubs - Ask homemakers clubs to promote radon testing in the community. - Provide radon literature to home-makers
Youth Organization Members	Informational (Awareness) Motivational	" "	- Host radon awareness programs for Youth Clubs - Ask youth to encourage their parents to test for radon - Assist youth in developing community radon projects.

Appendix F

JEFFERSON COUNTY SCHOOL DISTRICT AND RADON PROGRAM

1. Work cooperatively to establish a radon comunication outreach program through the school to parents, staff, and students.
2. Promote the Jefferson County School District radon testing project and the communication outreach program as a model for other school districts in the state and the nation.

MODEL COMMUNICATION OUTREACH

Audience

School Administrators	Building Maintenance Personnel
Teachers	Ancillary School Staff
Parents	Parent-Teachers Association
Students	

Message

Long-term exposure to elevated levels of rdon gas is associated with increased risk of developing lung cancer.

Testing for radon gas is easy and mitigation methods are effective.

All homeowners should test their homes. Schools, daycares, public and commerical buildings should also be tested.

If elevated levels are discovered, action should be taken to reduce the levels.

Appendix F

RADON COMMUNICATION OUTREACH PROGRAM THROUGH SCHOOLS

Audience	Type of Communication	Message	Method
School Administrators Building Maintenance Personnel	Technical/Support and Motivational	- Testing Protocols - Decision process after testing - Mitigation strategies - Technical assistance - Public disclosure - Encourage them to test their homes	Kentucky Educational Television-Radon in Schools Broadcast Spring/Fall 1991
Teachers Ancillary School Staff	Informational and Motivational	-Levels of radon in school, by room - Mitigation strategy - Encourage them to test their homes	- Dissemination of informational literature -Presentations through the Kentucky Education Association
Parent-Teacher's Association	Informational and Motivational	- Levels of radon in school, by room - Mitigation strategy - PTA can help school administrators to reach parents with radon information - Encourage them to test their homes	- Presentation at State and District Meetings and Workshops - Assistance to individual schools/districts - PTA host Radon Awareness Program -PTA distribute radon info to parents - Host testing campaigns
Parents	Informational and Motivational	-Levels of radon in school, by room -Mitigation strategy - Encourage them to test their homes	- District/School/PTA sponsored radon awareness programs - Distribution of radon literature through PTA/ District office
Students	Informational and Motivational	- Facts about radon and indoor air quality - How to improve air quality	- American Lung Association lesson on radon in "Growing Healthy" curriculum

RESIDENT INSTRUCTION
AGRICULTURAL EXPERIMENT STATION
COOPERATIVE EXTENSION SERVICE

REPLY TO

November 16, 1990

Dear Warren County Radon Action Committee Member:

This letter is to serve both as a notice of the next committee meeting and as a summary of what has been done so far, partly in an effort to keep absent committee members informed.

January 15, 1991 at 9:30-11:00 a.m. has been set for the next meeting which will be at the Warren County Extension Office,

At the first meeting on October 15, Jeana Phelps from the Kentucky Radon Program out of Frankfort was with us giving us an update on the radon situation nationwide as well as in Kentucky. She distributed packets of literature, a bumper sticker and a RADON tee-shirt.

Joan Martin and Terry Wilson from WKU distributed radon test kits made available by the American Lung Association. It has been agreed that people may obtain these kits for a $2.00 donation to the American Lung Association. The Warren County Extension Office obtained 500 of the kits from Joan for distribution to Homemaker Club members and others who may want them.

The rest of the meeting consisted of members getting acquainted with each other and finding out what our interests and concerns were regarding radon.

At the November 16 meeting, we continued getting acquainted, as we had some new committee members, and began discussing our mission statement and possible goals which we might wish to accomplish.

A sub-committee was formed to congeal our ideas and suggestions into a format which can be presented at the January 15 meeting for the entire committee's consideration. Serving on this committee are Terry Wilson as chairman, Joan Martin, Elaine Simmons and Bill Meinhardt.

(over)

Also enclosed is a committee membership list so all members will know who is involved and to what extent. If you know of others who are interested in serving on this committee, please feel free to tell them about the next meeting, or let me know and I will send them a notice.

Thank you very much for your interest and participation. We have a big job to do, but with coordination and working together we should be able to accomplish our goal.

Sincerely,

Session II:

Radon-Related Health Studies -- POSTERS

5466

OCCUPATIONAL SAFETY DURING RADON MITIGATION FIELD EXPERIENCE AND SURVEY MONITORING RESULTS

Jean-Claude F. Dehmel, CHP
S. Cohen & Associates, Inc.,
McLean, VA 20101
Peter Nowlan
R.F. Simon Company, Inc.
Barto, PA 19504
Eugene Fisher
U.S. Environmental Protection Agency
Office of Radiation Programs
Washington, DC. 20460

ABSTRACT

The U.S. Environmental Protection Agency (EPA) has initiated a radon mitigation project in homes located in Montclair, West Orange, and Glen Ridge, New Jersey. In these communities, numerous properties are contaminated with radium tailings which were initially introduced around homes as backfill and used as construction materials. In these homes, ambient radon concentrations are well above the 4 pCi/L EPA guideline. In support of radon mitigation activities, a comprehensive occupational health and safety (H&S) monitoring program has been implemented to assess working conditions. H&S activities include monitoring airborne concentrations for radon, asbestos, organic vapors, radioactivity, and total suspended particulates, and radiation exposures and loose surface alpha contamination levels.

Survey results indicate that all exposures are well within occupational radiation protection standards and OSHA criteria. Survey measurement results have been observed to vary depending upon existing conditions and type of on-going mitigation work. Typically, average radon levels vary from 0.4 to 32.5 pCi/L; radiation exposure rates range from 6 to 460 uR/h; surface contamination is generally below detection limits of 9 to 17 dpm/100 cm^2; long-lived radionuclides concentrations are $\leq 6.8 \times 10^{-13}$ uCi/mL; asbestos fiber concentrations vary from $\leq$0.002 to 0.016 fibers/cm^3; total suspended particulates personnel exposure limits vary from $\leq$0.01 to 0.65 mg/m^3; and organic vapors concentrations range from <0.36 to 13 ppm-TWA for compounds typically found in caulking compounds and PVC cements.

The work described in this paper was not funded by the U.S. Environmental Protection Agency and, therefore, the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

INTRODUCTION

The installation of radon mitigation systems involves potential exposures to different types of occupational hazards. Such hazards include exposure to radon and to those routinely experienced in light construction and building trades, e.g., home remodeling and improvement. In the context of this project, radiological occupational hazards, in addition to radon, include exposures to elevated ambient radiation levels due to the presence of soils contaminated with such radionuclides as Ra-226, U-238, and Th-232, and their decay products. Possible exposure pathways include ambient radiation, airborne radionuclides (radon gas, radon daughters, and resuspended particulates), and the presence of radioactive contamination (in soils and as loose surface). The installation of radon mitigation systems (e.g., subslab) requires that holes be drilled into concrete floors and foundation walls in order to tap soil gases and also necessitates the removal of some soils. Such activities have the potential to increase exposures and cause the spread of contamination.

The following presents and summarizes health and safety (H&S) monitoring data and results obtained during the course of radon mitigation activities conducted in 17 homes (1, 2). H&S activities include monitoring airborne concentrations for radon, asbestos fibers, organic vapors, long-lived nuclide particulates, and total suspended particulates/dusts (TSP), radiation exposure rates, and loose surface alpha contamination levels.

H&S MONITORING RESULTS

SOIL RADIONUCLIDE CONCENTRATIONS

In these communities, numerous properties are contaminated with radium tailings which were initially introduced around homes as a backfill and used as construction materials. The tailings originated from the extraction and purification process of radium from uranium bearing ores to produce luminous paints. Tailings and contaminated soils were discarded in adjacent properties and used by nearby communities. Previous characterization studies indicate that surface and subsurface Ra-226 concentrations are on the order of 1,500 and 4,500 pCi/g, respectively (3). The range of Th-232 concentration is approximately the same as radium. The concentrations of U-238 and U-234 are lower, with the highest concentration being reported at 310 pCi/g.

In support of the field work, several soil samples were taken and analyzed for the presence of U-238, Ra-226, Th-232, and K-40. The analyses were performed by GeLi gamma spectroscopy. The results of such analyses are shown below (Table 1).

The data indicate that none of the soil sample concentrations approach the results of earlier characterizations. For the radionuclides considered here, the maximum soil concentrations are 27 pCi/g for U-238, 59 pCi/g for Ra-226, and 5.9 pCi/g for Th-232. Background concentrations of these radionuclides in Northern New Jersey soils are typically <1.0 pCi/g. The presence of naturally occurring K-40 was determined for the purpose of providing additional information with which to assess the response of portable radiation survey meters. Past experience has shown that since the concentration of K-40 in soil varies, the detection of elevated exposures rates could be interpreted as radium contamination, especially when Ra-226 is present at lower concentrations. Soil sample analyses confirm that K-40 concentrations vary by a factor of two, from 7.0 to 15.0 pCi/g.

SURFACE CONTAMINATION

The presence of surface contamination was monitored by conducting smear surveys and by scanning areas with portable alpha ZnS(Ag) survey meters. Typically 10 to 20 smears were taken in each home whenever contaminated soils were exposed. The number of smears taken and their survey locations were based on

TABLE 1. MAXIMUM SOIL RADIONUCLIDE CONCENTRATIONS

Residence ID No.	Radionuclide concentrations* - pCi/g U-238	Ra-226	Th-232	K-40
1 A-211	4.4	18.0	2.9	11.0
153 C-315	<1.0	1.4	1.6	13.0
30 F-142	8.1	9.2	1.8	9.4
32 F-143	12.0	16.0	2.1	7.0
6 J-242	4.2	4.6	2.1	9.7
8 J-243	9.4	10.0	2.0	9.2
21 L-321	<1.0	1.1	5.9	15.0
26 L-322	2.2	1.7	1.6	10.0
53 N-163	<0.5	2.9	0.8	8.8
56 N-164	2.4	3.1	2.2	13.0
64 N-166	27.0	35.0	2.6	9.2
66 N-167	24.0	59.0	1.6	9.2
26 V-173	21.0	40.0	1.6	9.7
28 V-174	<2.0	3.7	2.1	11.0
37 V-178	13.0	6.7	1.9	7.3

* Soil sample analyses performed by GeLi gamma spectroscopy. Concentrations results are expressed for dry weights.

the results of direct reading radiation survey meters and the type of intrusive activities being conducted. All smears were counted for five minutes using a bench-top alpha ZnS(Ag) counter in order to resolve the maximum contamination limit of 20 dpm/100 cm^2. The results of such analyses are shown below (Table 2). The data indicate that all results, except for a few, are below the maximum contamination limit.

In a few instances, smear results were found to hover about the limit of 20 dpm/100 cm^2. When those smears were recounted, typically 2 to 3 later hours, all results fell within the instrumentation's lower limit of detection, indicating that the initial activity was due to radon decay products. This conclusion was also confirmed by submitting such smears to more rigorous laboratory analyses.

TABLE 2. TYPICAL ALPHA SURFACE CONTAMINATION LEVELS

	Surface contamination levels* - dpm/100 cm^2	
Residence ID No.	Results at or below the lower limit of detection	Results above the lower limit of detection
1 A-211	≤11.9	
2 A-212	≤ 9.4	
145 C-312	≤12.2	
153 C-315	≤12.2	
30 F-142	≤11.9	
32 F-143	≤11.9	
6 J-242	≤ 9.4	
8 J-243	≤ 9.4	
21 L-321	≤13.2	15.3
26 L-322	≤13.2	
53 N-163	≤13.2	
56 N-164	≤17.1	
64 N-166	≤11.9	
66 N-167	≤14.1	
26 V-173	≤ 9.4	
28 V-174	≤11.9	
37 V-178	≤10.4	13.1 - 25.0

* Analyses were performed by gross alpha counting using a ZnS(Ag) counter/ratemeter. Contamination results are for smears or wipes taken over an area of 100 cm^2, ca 4" x 4".

RADIATION EXPOSURE RATES

Ambient radiation exposure levels were monitored in all work areas, including basements, lowest ground floors, crawl spaces, and outdoor areas requiring access or where work was being performed. Measurements were made using portable NaI(Tl) micro-R-meters. Survey measurement points included ambient areas at one meter above the floor or ground, and on contact with floors, foundation walls, and soil. The results of such surveys are shown below (Table 3). The data indicate that ambient exposure rates vary greatly, typically up to 10 times above the ambient background level of 8 to 9 uR/hr. Any measurement results in excess of twice background is generally considered to be anomalous. Contact radiation levels were shown to vary even more significantly, ranging from about 15 to 460 uR/hr. In terms of characterizing radiation doses, ambient radiation levels are more representative of personnel exposures than contact measurements. Exposures to higher contact radiation levels, when they did occur, were of relatively brief durations.

RADON CONCENTRATIONS

Radon concentration levels were measured using continuous radon monitoring equipment. Radon levels were printed hourly during the course of the work. All general work areas and zones were ventilated using portable ventilation systems and vacuum cleaners, respectively. Ventilation systems introduced fresh air from the outside and vacuum cleaner exhausts were discharged outdoors. Radon monitoring results are shown below (Table 4). The data indicate that average and maximum ambient radon concentration levels were typically less than 5 pCi/L and as high as 66 pCi/L, respectively. In one instance, basement radon levels shot up to 66.1 pCi/L over a four hour period in spite of the on-going active ventilation. This sudden radon excursion was corrected by pressurizing the basement instead.

LONG-LIVED PARTICULATE RADIONUCLIDES

Air samples were taken to assess ambient airborne radionuclide concentrations whenever intrusive work or sampling activities were in progress. Monitoring involved taking air samples through 47 mm glass fiber filters. Sample durations typically reflected the length of on-going work activities, up to 9 hours per day, and a nominal sampling flow rate of 40 LPM. All filters were counted for ten minutes using a bench-top alpha ZnS(Ag) counter in order to resolve the concentration limit of 4.4 E-12 uCi/mL for total gross alpha.

TABLE 3. AMBIENT AND CONTACT RADIATION EXPOSURE RATES

Residence ID No.	Range of radiation exposure rates* - uR/hr. — Ambient radiation exposure rates at waist height (1 m.)	Range of radiation exposure rates* - uR/hr. — Contact radiation exposure rates on ground and floor
1 A-211	10 - 25	10 - 32
2 A-212	7 - 20	7 - 32
145 C-312	10 - 190	11 - 460
153 C-315	11 - 17	14 - 26
30 F-142	10 - 90	11 - 150
32 F-143	13 - 75	12 - 200
2 J-241	8 - 20	8 - 34
6 J-242	9 - 23	9 - 36
8 J-243	6 - 12	7 - 18
21 L-321	7 - 11	8 - 13
26 L-322	7 - 12	9 - 14
27 L-S27	7 - 12	7 - 15
53 N-163	8 - 13	9 - 14
56 N-164	10 - 15	10 - 30
64 N-166	15 - 80	13 - 240
66 N-167	20 - 50	15 - 100
26 V-173	8 - 18	9 - 28
28 V-174	8 - 60	8 - 140
37 V-178	10 - 34	10 - 40

* Measurements taken using a portable NaI(Tl) micro-R survey meter. Results represent range of exposures rates routinely observed in basements or lowest floor levels, and outdoors in areas such as sidewalks, yards, and drive and walkways.

The filters were counted again, typically 2 to 3 hours later, to discern the presence of long-lived radionuclides from radon decay products. The results of such sampling surveys are shown below (Table 5). The data indicate that airborne concentrations were typically below the instrumentation's lower limit of detection, about ≤6.8 E-13 uCi/mL. This conclusion was also confirmed by subsequently subjecting air sample filters to more rigorous laboratory analyses.

TABLE 4. RANGE OF RADON CONCENTRATION LEVELS

Residence ID No.	Typical radon concentration levels* - pCi/L.		
	Average	Low	High
1 A-211	1.0	0.4	1.7
2 A-212	1.0	0.1	2.4
145 C-312	2.7	2.4	3.9
153 C-315	0.4	0.4	1.2
30 F-142	4.3	2.8	7.2
32 F-143	1.5	0.4	2.7
6 J-242	0.9	0.3	1.8
8 J-243	0.7	0.3	1.7
21 L-321	2.7	1.0	11.8
26 L-322	0.6	0.1	1.2
53 N-163	1.9	0.1	4.7
56 N-164	1.7	0.1	23.4
64 N-166	32.5	2.8	66.1
66 N-167	1.2	0.9	3.5
26 V-173	3.4	1.1	15.1
28 V-174	2.3	1.0	2.6
37 V-178	1.3	0.9	1.7

* Measurements taken using portable Femto-Tech Model R210F radon monitors equipped with continuous data recorders. Results were printed out hourly to monitor levels. Radon concentrations represent ambient levels in basements or lowest ground floors measured with on-going active ventilation.

TOTAL SUSPENDED PARTICULATES (TSP)

Some work activities, such as drilling, grinding, etc, have the potential to generate airborne suspended particulates (TSP). The air sampling program and system described above were also used to assess the presence of TSP in the work environment. All filters were pre-weighed before being used and then weighed again when sampling was completed. Both weighings were performed using a laboratory micro-balance. The associated airborne dust concentrations are shown in above (Table 5). The data indicate that all results are below the OSHA limit of 10 mg/m^3 (4). The highest and lowest measurable TSP concentrations observed were 0.65 and 0.04 mg/m^3, respectively.

TABLE 5. GROSS ALPHA AIRBORNE RADIONUCLIDE AND TOTAL SUSPENDED PARTICULATE CONCENTRATIONS

	Airborne concentrations*		
Residence ID No.	Sampling time (hr.)	Gross alpha concentrations (uCi/mL) &	Suspended Particulates (mg/m^3) #
1 A-211	6.9	≤4.0E-13	0.17
2 A-212	7.9	≤5.2E-13	0.26
145 C-312	8.5	≤6.5E-13	no data
153 C-315	6.7	≤2.4E-13	≤0.03
30 F-142	7.1	≤6.8E-13	≤0.01
32 F-143	7.7	≤5.5E-13	0.18
6 J-242	6.9	≤2.1E-13	≤0.03
8 J-243	5.2	≤1.5E-12	≤0.03
21 L-321	8.0	≤4.7E-13	0.15
26 L-322	6.5	≤4.3E-13	0.15
53 N-163	7.7	≤4.8E-13	0.16
56 N-164	8.5	≤3.9E-13	≤0.02
64 N-166	8.8	≤4.8E-13	0.04
66 N-167	8.3	≤3.8E-13	0.20
26 V-173	9.0	≤4.5E-13	0.65
28 V-174	8.0	≤1.9E-13	≤0.02
37 V-178	8.9	≤3.2E-13	0.09

* Measurements taken using a portable sampling pump and 47 mm glass fiber filters. Sampling flow rate is typically 40 LPM. Air concentrations represent ambient levels in basements or lowest floors measured with on-going active ventilation. Sampling times represent typical duration of intrusive work which could result in the generation of elevated airborne suspended dust and radioactivity concentrations. A single filter was used to simultaneously assess the presence of both long-lived particulate nuclides and total dust.

& Filter samples were analyzed first for gross alpha activity using a ZnS(Ag) alpha scaler at the work site and then subjected to laboratory GeLi gamma spectroscopic analyses.

\# Filters were pre-weighed before being used and weighed again after sampling was completed. Both weighings were performed using a micro-balance under laboratory conditions.

106

FIBER (ASBESTOS) CONCENTRATIONS

Since the work was performed in homes which are known to have asbestos containing materials (ACM), air samples were taken to determine the presence of airborne fibers in all work areas. Samples were taken by drawing air through a 25 mm open cassette with a mixed cellulose ester filter (MCE). The selected sampling and analytical methods were based on OSHA approved methods (NIOSH 7400 - Phase Contrast Microscopy) (5). Sampling durations and flow rates were adjusted to reflect the constraints of the NIOSH procedure for total fiber loadings. The airborne fiber concentrations are shown below (Table 6). The data indicate that all results are below the OSHA limit of 0.2 fiber/cm^3, 8-hr TWA (4). It should be noted that PCM resolves all fibers with a specific aspect ratio (length and diameter), whether they are asbestos or not. In order to assess the presence of asbestos fibers, one sample with the highest fiber density (43.3 f/mm^2) was subjected to further analysis (transmission electron microscopy - TEM) (6). The results revealed that a fewer number of non-asbestos fibers were measured (14.4 f/mm^2). Such fibers were identified to be gypsum, cellulose, and material containing calcium.

ORGANIC VAPOR CONCENTRATIONS

The installation of radon mitigation systems require the use of caulking and sealing compounds, sealing foams, and PVC pipe cements. As these compounds are applied, and during the curing process, organic vapors are released in the work environment. In order to assess personnel exposures to such chemical compounds, organic vapor monitor (passive diffusion) were worn by individuals involved in applying caulks, sealants, and PVC cements. The monitors were worn for the duration of these activities since such functions are typically of short duration (2 to 4 hours). The monitors were supplied and analyzed by 3M (7). The organic vapor concentration results are shown below (Table 7). The selection of organic compounds to be analyzed by 3M was based on the information contained in the MSDS supplied with such commercial products. The organic vapor concentration results represent exposure levels in all work areas routinely accessed to support the installation of radon mitigation systems. The data indicate that for the selected compounds, ambient concentrations were well below the OSHA permissible exposure limits and ACGIH threshold limit values (4, 8). The highest observed organic vapor concentrations was due to methyl ethyl ketone (MEK), at 13 ppm. The corresponding 8-hour TWA limit is 200 ppm.

TABLE 6. FIBERS (ASBESTOS) CONCENTRATION LEVELS

Residence ID No.	Airborne fibers concentration levels* - f/cm^3		
	fibers/cm^3	fibers/mm^2	
1 A-211	≤0.005	12.7	
2 A-212	≤0.005	10.2	
13 A-112	≤0.005	16.6	
120 C-311	≤0.005	33.1	
153 C-315	≤0.005	28.0	
14 E-121	0.012	62.4	
26 F-173	≤0.005	29.3	
30 F-142	0.007	19.1	
32 F-143	0.016	43.3	PCM data&
32 F-143	≤0.003	14.0	TEM data&
6 J-242	≤0.005	19.1	
8 J-243	≤0.006	30.6	
21 L-321	≤0.005	0.0	
26 L-322	0.011	28.0	
27 L-S27	≤0.005	30.6	
25 M-251	0.007	25.5	
46 N-161	≤0.002	0.0	
53 N-163	≤0.005	8.9	
56 N-164	0.007	24.2	
58 N-168	0.007	33.1	
64 N-166	≤0.005	12.7	
66 N-167	≤0.005	34.4	
33 R-341	0.006	31.8	
55 R-343	≤0.005	24.2	
26 V-173	0.008	29.3	
28 V-174	0.012	24.2	
35 V-177	≤0.005	15.3	
37 V-178	≤0.005	11.5	

* Fiber concentrations represent ambient levels in basements or lowest floor levels measured with on-going active ventilation. Measurements were taken using a portable sampling pump and 25 mm MCE filters in open face cassettes. MCE filters were analyzed by NIOSH method 7400 - Phase Contrast Microscopy (5).

& One sample, 32 F-143, was also analyzed via transmission electron microscopy (TEM) using U.S. EPA Level II Method (6). Analysis was performed following the results of the PCM analysis. The same sample was used for the TEM analysis.

TABLE 7. ORGANIC VAPOR MONITOR CONCENTRATION LEVELS

	Typical organic vapor concentrations* - ppm			
Residence ID No.	Work activity	Organic compounds	Vapor concentrations	TWA[&] limit
53 N-163	Sealing & caulking	MEK	< 1.00	200
		Toluene	< 0.84	100
		Xylene	< 0.66	100
64 N-166	PVC cementing	MEK	13.0	
		Cyclohexanone	0.53	25
66 N-167	PVC cementing	MEK	6.55	
		Toluene	< 0.43	
		Cyclohexanone	< 0.49	
66 N-167	Sealing & caulking	Toluene	< 0.56	
		Perchloro-ethylene	< 0.36	25
		P. Glycol mono methyl ethyl acetate	< 0.46	5[#]
37 V-178	Sealing & caulking	Acetone	< 2.30	75
		MEK	< 1.83	
		Xylene	< 1.21	

* Measurements taken using 3M Model 3510 passive diffusion organic vapor monitors issued to personnel. Selection of organic compounds was based on information provided in MSDS supplied with commercial products routinely used in radon mitigation. Organic vapor concentrations represent exposure levels in all work areas routinely accessed to support the installation of radon mitigation systems with on-going active ventilation in the lowest ground floors and normal ventilation in the remaining upper floors.

& TWA limits reflect OSHA permissible exposure limits (PEL) (4).

\# Based on ACGIH threshold limit values (TLV) (8).

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The results shown above indicate that all personnel exposures were well within recognized radiation protection standards as well as project administrative limits. The adopted radiation exposure limit for this project was set at 500 mrem, same as for the general public, as opposed to 5,000 mrem for occupationally exposed radiation workers. Furthermore, an action level of 100 mrem was established for the purpose of assessing on-going work activities and associated radiation exposures. Dosimetry results from radiation badges (TLDs) revealed that monthly exposures were below the TLD's response level of 10 mrem for X and gamma rays (9). Personnel radon exposures were monitored by using alpha track etch detectors (ATDs) (10). ATD radon concentration results ranged from 0.3 to 5.2 pCi/L. Cumulative radon exposures ranged from 30 to 104 pCi-days/L for one month monitoring periods. Exposures to airborne long-lived particulate radionuclides, total suspended solids, asbestos fibers, and organic vapors were well within the applicable OSHA permissible exposure limits.

RECOMMENDATIONS

The H&S monitoring results revealed that by adopting simple protective measures, personnel exposures can be maintained well below occupational standards and, in some instances, at the threshold of measurement detection limits. Some of the applied protective measures include working in well ventilated areas, judicious use of local exhaust ventilation at the source of contaminants, application of dust suppression techniques, use of the functional sections of a mitigation system to minimize radon exposures and resuspended particulates while completing its installation, use of containment methods to minimize the spread of contaminants, and restricting personnel traffic in work areas. The use of monitoring equipment has shown to be also helpful in the detection of trends in ambient radiation exposure rates and levels of contaminants. Routine surveillance of all work activities has also allowed the timely detection of potentially problematic situations. The radon concentration excursion and interpretation of radon decay products to alpha surface contamination were two such examples. In both instances, simple monitoring and measurement techniques were applied to identify and correct the situation. Excluding the presence of contaminated soils, these H&S monitoring results indicate that such protective measures and monitoring methods can also be applied in the installation of radon mitigation systems under conventional conditions.

REFERENCES

1. S. Cohen & Associates, Inc. Work Plan - House Evaluation Program Applied to Superfund Sites - Montclair, West Orange, and Glen Ridge, New Jersey, prepared for the U.S. Environmental Protection Agency, Office of Radiation Programs under contract No. 68D90170, Work Assignment No. 1-39, May 1990

2. S. Cohen & Associates, Inc. Health and Safety Plan - House Evaluation Program Applied to Superfund Sites - Montclair, West Orange, and Glen Ridge, New Jersey, prepared for the U.S. Environmental Protection Agency, Office of Radiation Programs under contract No. 68D90170, Work Assignment No. 1-39, May 1990

3. Camp Dresser & McKee, Inc. Supplemental Feasibility Study for the Montclair/West Orange and Glen Ridge Radium Sites, Vol. 4, prepared for the U.S. Environmental Protection Agency, Region II, Edison, NJ, April 3, 1989.

4. Occupational Safety and Health Administration, Air Contaminants - Permissible Exposure Limits, Title 29, Code of Federal Regulations, Part 1910.1000, OSHA 3112, 1989.

5. National Institute for Occupational Safety and Health, NIOSH Method 7400, Fibers, 2/15/84, Cincinnati, OH.

6. Yamate, G., Agarwal, S.C., and Gibbons, R.D. Methodology for the Measurement of Airborne Asbestos by Electron Microscopy, Draft Report, U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC, 1984.

7. Occupational Health & Safety Products Division, Organic Vapor Monitors #3500/3510 - Instruction and Use Manual, 3M, St. Paul, MN.

8. American Conference of Governmental Industrial Hygienist, Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, 1990-1991, Cincinnati, OH.

9. Tech/Ops Landauer, Inc. Gardray TLD Dosimetry, Radiation Dosimetry Reports, 6/30/1990 to 11/30/1990, Glenwood, IL.

10. Tech/Ops Landauer, Inc. Radon DDOS ATDs, Radon Monitoring Reports, 4/3/1990 to 11/12/1990, Glenwood, IL.

THE EFFECT OF PASSIVE CIGARETTE SMOKE ON WORKING LEVEL EXPOSURES IN HOMES

by: Raymond H. Johnson, Jr., Certified Health Physicist, and
Randolph S. Kline, Laboratory Supervisor
Key Technology, Inc., P.O. Box 562
Jonestown, PA 17083

Eric Geiger, Certified Health Physicist, and
Augustine Rosario, Jr., Laboratory Director
Radon QC, 2857 Nazareth Road,
Palmer, PA 18043

ABSTRACT

Numerous studies have evaluated the combined effects of cigarette smoke and inhalation of radon decay products on the risk of lung cancer to smokers. In 1988 the National Academy of Sciences concluded that the risk of lung cancer is about 10 times greater for smokers than for nonsmokers at the same Working Level exposures. However, very little attention has been given to the effects of passive cigarette smoke and radon decay product exposures to nonsmokers. Preliminary studies (presented by the authors at the annual conference of the American Association of Radon Scientists and Technologists - Oct. 4 - 6, 1990) showed that even a single cigarette drastically increased the Working Level exposures in homes. Consequently, a cigarette smoker not only increases his/her own risk, but may also increase the risk to all occupants of the same dwelling due to an increase in Working Level exposures.

This paper presents the results of additional measurements to evaluate the effects of typical cigarette smoking patterns in a home. The study simulated the smoking habit of approximately a one pack a day smoker. Continuous measurements were made on radon gas levels, Working Levels, and corresponding equilibrium ratios. Working Levels were found to increase rapidly after lighting of cigarettes and to remain elevated for several hours. Cigarette smoke provides a significant source of aerosols for attachment of radon decay products in homes. Furthermore, the airborne particles from cigarette smoke remain in the air for many hours after the visible smoke has dissipated. Consequently, the increase in Working Levels and equilibrium ratios persists long after the smoking stops.

Since the risk of exposure to radon decay products is also significantly affected by the fraction of unattached polonium-218, then additional studies are recommended to evaluate unattached fractions, as well as aerosol concentrations and particle size distributions. This paper confirms the potential risks to nonsmokers from increases in Working Levels due to passive smoke in homes and points to needs for further studies to document other risk factors.

INTRODUCTION

The connection between exposure to radon decay products and subsequent lung cancers in uranium miners has been studied since the early 1950's. Continuing studies of uranium miners in the United States, Czechoslovakia, Sweden, and Canada have confirmed that uranium miners develop more lung cancers than other types of miners or the general population according to a 1984 report by the National Committee on Radiation Protection and Measurements (1). These studies indicate that about 10 additional lung cancers occur per year for each Working Level Month (WLM) exposure to one million persons. The 1988 report of the Committee on the Biological Effects of Ionizing Radiation (BEIR IV) concluded that lifetime exposures to radon decay products could result in an additional 350 lung cancer deaths for each million person WLM (2). The Environmental Protection Agency estimates that 20,000 lung cancer deaths a year may be caused by exposures to radon decay products in homes (3).

The connection between cigarette smoking and lung cancer is also well documented. Kabat (4) shows that, among lung cancer deaths in five countries, 83 - 94% are due to cigarette smoking by men and 57 - 80% by women. In the United States the Surgeon General reported 106,000 lung cancer deaths among smokers in 1986. The National Academy of Sciences (5) also evaluated the risk to nonsmokers from passive exposure to tobacco smoke, usually from a smoking spouse. This study found an increase in risk of about 34% compared to nonsmokers without exposure to tobacco smoke. Cigarette smoking is clearly the primary cause of lung cancer in the U.S.

Since radon decay products are also clearly a cause of lung cancer, the question arises on how these two causes may combine. BEIR IV concluded that smokers have about 10 times greater risk than nonsmokers for the same WLM exposures. This study determined that the combined effect of cigarette smoke and radon decay products is synergistic. The two effects combine multiplicatively rather than additively. This means the combined effects are worse than the sum of the two risks alone. Recognizing that cigarette smoke drastically increases the radon lung cancer risk to smokers also raises questions about the combined effects on nonsmokers who are passively exposed to environmental tobacco smoke.

EFFECT OF CIGARETTE SMOKE ON INDOOR AIR

A review of studies done by A.C. George (1) indicates that even one cigarette will profoundly increase the concentration of airborne particles. In fact, any human activity will increase the particle concentration several fold over the normal quiescent value. The fumes from cooking, burning of candles or incense, spraying of aerosols, ultrasonic humidifiers, or other similar activities will also increase the concentration of particles in air (1). Conversely, air conditioning or air cleaning systems that remove particulates by filtration or electrostatic precipitation will reduce indoor aerosol concentrations. For example, Moeller (6) indicates that a fan to circulate the air plus a positive ion generator will reduce aerosols and the airborne concentration of radon decay products by 90 to 95 percent. The lowest concentration of airborne particles likely to exist in homes is in the order of 1,000 to 10,000 particles per cubic centimeter.

Any activity that changes aerosol concentrations will also affect the equilibrium ratio between radon gas and radon decay product concentrations. The quantity of decay products in the air and the equilibrium ratio go up as the aerosol concentration goes up. This is because airborne radon decay products are mostly attached to aerosols. Decay products that do not attach to aerosols (the unattached fraction) tend to quickly plateout on walls and other surfaces and are removed from the air. As the aerosol concentration goes up, there are more particles for attachment of radon decay products which then remain in the air longer that those that are unattached.

The quantity of radon decay products in the air is normally measured in terms of Working Levels. Working Levels are commonly measured by collecting airborne dust and associated radon decay products on a filter and measuring the collective alpha particle emissions. Consequently, for a given radon concentration, the measured Working Levels tend to increase with increasing aerosol concentrations and increasing equilibrium ratios, both of which are likely to increase with the introduction of cigarette smoke into the air as noted above. Since Working Levels are the primary measure of exposure to radon decay products and corresponding lung cancer risk, anything that affects Working Levels may also affect estimates of lung cancer risk. Therefore, increases in Working Levels due to cigarette smoke could increase risk of lung cancer for any concentration of radon.

EFFECT OF CIGARETTE SMOKE ON WORKING LEVELS

Initial studies of the effect of cigarette smoke on Working Levels were conducted by Eric Geiger at Radon QC in 1988 (7). A single cigarette was burned in a radon chamber while Working Levels were measured hourly. The Working Levels were found to increase significantly while the radon gas concentration remained about the same. These observations confirmed the work of other investigators. Namely, cigarette smoke increases aerosol concentrations and Working Levels. Discussion of these observations among the authors in the spring of 1990, however, led to several questions. First of all, what do we know about levels of cigarette smoke and Working Levels in homes? Secondly, what is known about the lung cancer risk to occupants in homes where the Working Levels are affected by cigarette smoke?

Numerous studies are reported that evaluate the combined effects of cigarette smoke and exposure to radon decay products in terms of risk to the smoker. However, little research has been done that considers the effects on nonsmoking occupants of homes due to increased Working Levels attributed to cigarette smoke.

PURPOSE OF THIS STUDY

This paper has three purposes. One is to highlight the fact that cigarette smoking may increase the lung cancer risk from exposure to radon decay products for all occupants of a smoker's home. The second is to present preliminary findings on Working Level measurements related to cigarette smoke in a radon chamber and in typical homes. Thirdly, this paper identifies several needs for further research to answer questions about risks to all occupants related to cigarette smoking in the home or other buildings.

MEASUREMENT TECHNIQUES

This paper presents the results of four sets of measurements. One study was conducted in a radon chamber at Radon QC, two studies were done in the basements of typical homes; one in Nazareth, PA and the other in Bethlehem, PA., a final study was done in the living room of a home in Rockville, MD.

Radon Chamber - The study was conducted in the Red Chamber at Radon QC. This chamber has the highest radon levels of the three chambers available for radon and radon decay product calibrations at Radon QC. The Red Chamber is a walk-in room about five feet by nine feet with an eight-foot ceiling. It is equipped with calibration ports and a viewing window. This chamber normally runs at radon levels from 200 to 600 pCi/L. The radon and decay product levels are constantly monitored with a continuous radon monitor, continuous working level meter, and an alpha spectrometer. The chamber is operated at slight negative pressure and cigarette smoke was drawn in through one of the calibration ports.

Nazareth House - This is a 50 year old wood frame house with a full basement. The basement is approximately 31 feet by 26 feet with concrete walls and a concrete floor. One corner of the basement, about 19 feet by 12 feet, is partitioned off leaving an open L-shaped area where the experiment was conducted. No one in this house smoked cigarettes.

Bethlehem House - This is a one year old house with an open basement area of about 43 feet by 15 feet. The basement has concrete floors and walls. A person in this house is a heavy smoker.

Rockville House - This is a two story colonial all masonry house (cinder block and brick) on a concrete slab without a basement. The experiment was conducted in the living room, which is about 15 feet by 20 feet. The living room is connected by an open archway to an adjoining dining room. The open area of the two rooms is about 15 feet by 35 feet. Entrances to both rooms were closed with bifold doors.

INSTRUMENTATION

In each study measurements of radon gas and radon decay products were made hourly. Working Level measurements were made with an Eberline model WLM-1A. This detector draws an air sample through a filter at a flow rate of 0.10 to 0.18 liters/minute. Alpha particle emissions from the aerosols trapped on the filter are measured with a silicon diffused junction alpha detector. Both radon (radon-222) and thoron (radon-220) decay products are measured. The thoron contribution is estimated by observing the decay rate after the sampler is shut off. Equilibrium between radon and decay products was calculated assuming that only radon-222 was measured. Accuracy of this detector is related to the sampling time, calibration of the flow rate, and calibration of counting efficiency.

Radon gas samples were measured with an Eberline model RGM-3 continuous radon monitor. Air is drawn at 6 liters/minute through a filter to remove particulates before counting alpha emissions with a zinc sulfide phosphor. This instrument will measure alpha emissions from both radon and thoron. However, the 56 second half-life of thoron should prevent very much getting into the detector. We calculated the radon/decay product equilibrium assuming that all the alpha emissions came from radon-222.

Since both the radon gas and decay product monitors are used primarily for determining levels in the radon chambers at Radon QC, these instruments are intercalibrated quarterly with the Environmental Measurements Laboratory (EML) of the Department of Energy.

CIGARETTE SMOKE

Cigarette smoke was introduced into each room by lighting a 100 mm filtered cigarette and allowing it to burn in a cup or ashtray. The cigarettes were not smoked by anyone, but simply allowed to burn by themselves. The cigarettes required about 10 minutes to burn. The burning cigarettes were placed about three feet from an outside wall and were about 12 to 15 feet from the measuring instruments. In the Nazareth and Bethlehem houses a single cigarette was burned each 24 hours. In the Rockville house an attempt was made to simulate a typical smoking pattern of a one pack a day smoker. Approximately two packs of cigarettes were burned in this house between a Friday night and Sunday night of the experiment.

RESULTS

RADON CHAMBER STUDY

The data on the effect of cigarette smoke in the Red Chamber at Radon QC are shown in Figure 1 and Table 1. Two readings collected before introducing cigarette smoke into the chamber showed radon at about 310 pCi/L and Working Levels at about 0.4. This gave an equilibrium of about 14%. After burning one cigarette, the Working Levels went up to 2.2 and the equilibrium went up to 71%. These increases took about four hours due to the time needed for ingrowth of decay products to reach a new equilibrium. The increases also persisted for many hours, such that even 24 hours later the Working Level was still at 1.14 (more than double the original level) and the equilibrium was at 24% (nearly double the initial level). The burning of a second cigarette caused the Working Levels to move up to about 2.4 and stay there for several hours.

The main observation from this radon chamber study was that the smoke from a single cigarette drastically increased the concentration of radon decay products in the air as measured by Working Levels. Furthermore, the increased levels persisted for more than 24 hours, long after any visible evidence of cigarette smoke was gone. Two factors could account for these observations. One is that the radon chamber has a relatively low ventilation rate. Secondly, the air in this chamber is relatively low in aerosol concentration as indicated by the low percent equilibrium before starting the experiment. Since both of these factors could be substantially different in typical homes, the next part of the study was to repeat the cigarette experiment in homes.

NAZARETH HOUSE

The data gathered on the effects of passive smoke in this house are shown in Figure 2 and Table 2. As observed in the radon chamber, after a cigarette was burned the Working Levels and percent equilibrium both increased for several hours. After about six hours both of these effects began decreasing. Presumably these decreases are due to dilution from the normal ventilation in the basement area. Two other observations were noted in this house. One was the normal diurnal variation in radon gas concentrations. The other was that the percent equilibrium increased substantially in the six hours before the burning of a cigarette. This would indicate that some other source of aerosol was introduced into the basement air prior to the cigarette experiment. Since this increase occurred between 9 a.m. and 3 p.m., it follows the typical pattern related to normal daytime activities in a home, although we cannot attribute a specific cause to the increase.

The Working Level monitor in this house also recorded an 8% contribution of thoron decay products to the Working Level measurements. This would account for percent equilibrium values greater than 100%. This observation confirms a 1988 report by the NCRP which notes that indoor air can have significant amounts of the thoron decay product, lead-212 (4).

BETHLEHEM HOUSE

Two cigarettes were burned in the basement of this house at a 24 hour interval as noted in Figure 3 and Table 3. After the first cigarette, both the Working Levels and the percent equilibrium increased as noted in the Nazareth House. However, the Working Levels began decreasing within three hours. The percent equilibrium continued to increase for six hours. After burning a second cigarette on the next day the Working Levels dropped, although there was a general increase in the percent equilibrium. The decrease in Working Levels may be attributed to the decrease of radon concentration by a factor of two in the twelve hours following the cigarette burning.

This house also had a 13% contribution from thoron decay products to the Working Level measurements. Therefore, the lowest equilibrium value was 62%. Several times the equilibrium ratio went over 100%. The data in Table 3 (Continued) show that during the night of July 3-4, 1990, the equilibrium went up to 121%. We cannot account for this increase, although it would appear to be related to an increase in aerosol concentration. The overall high levels of percent equilibrium in this home could be due to regular cigarette smoking by an occupant. Since the percent equilibrium began increasing after 6 p.m., the increase could be due to smoking in the early evening hours.

ROCKVILLE HOUSE

The first observation of note in this house is that the radon gas levels varied widely during the 65 hours of the study, as shown in Figure 4 and Table 4. Initial levels of about 8 pCi/L at midday on Friday, January 11, 1991, rose to a high of about 22 pCi\L on Saturday morning and gradually decreased again to about 2.1 pCi\L on Sunday afternoon. We believe this ten-fold variation in radon levels was likely due to changes in weather conditions. On Friday morning a new wet snow fell on already snowcovered and frozen ground. The wet snow then changed to heavy rain during the day on Friday, while the outdoor temperatures increased from about 30 up to 40 degrees Fahrenheit. The clouds cleared on Saturday with cooler temperatures and sunshine through Sunday.

The wide variation in radon levels during this experiment also serve to highlight two other factors regarding radon measurements. One is that any readings taken during the day on Friday would have shown unusually high radon levels that are probably not typical for this house. This is another indication that short term measurements of a few hours, or even 24 hours, may give radon levels that are not representative of average conditions. The other factor has to do with how well charcoal canisters measure radon when the levels vary widely during the exposure period. Eight open-face charcoal canisters were placed in pairs around the living room for 72 hours to measure radon during the same time as the continuous radon monitor. The two canisters next to the continuous monitor gave an average reading of 4.4 pCi/L compared to an average of hourly readings of 7.69 pCi/L. Apparently, the canisters were affected more by the radon levels at 2 to 4 pCi/L during the last 24 hours of exposure than the levels of 8 to 20 pCi/L during the first day of exposure. Another observation of note also was that the six canisters placed nearer to the outside walls of the living room gave readings of 12 to 27 percent higher than the canisters near the inside wall next to the continuous monitor. Therefore, placement of canisters can also affect the readings substantially.

The times and the number of cigarettes burned are given in Table 4. We began lighting cigarettes on Friday evening to represent smoking after dinner and during the evening such as might occur while watching television. One or two cigarettes were lighted in the morning as typical of someone having a cigarette after breakfast. No other cigarettes were burned during the day on Saturday. Eight cigarettes were burned between 7:15 pm and 9:15 pm that night. On Sunday, six cigarettes were burned near noontime and another ten that evening to conclude the experiment. At most times, two cigarettes were burned at the same time to represent two people smoking together.

As in the other homes, both the Working Levels and the percent equilibrium increased significantly following the burning of each cigarette. These parameters remained elevated for three to six hours after each group of cigarettes. The effects persisted longer when more cigarettes were lighted in a short time, such as was done in the evenings during this study. The percent equilibrium values varied from a low of about 20 up to a high of about 70 after the introduction of cigarette smoke into the air. The lowest equilibrium values occurred in the morning hours around five or six am. The Working Level values also increased after each cigarette lighting even though the radon levels were falling for most of the study after midnight on Friday.

DISCUSSION AND CONCLUSIONS

Both the radon chamber experiment at Radon QC and the measurements in the basements and living areas of typical homes showed that cigarette smoke leads to a significant increase in Working Levels and percent equilibrium. To the extent that Working Levels are an indicator of health risk from exposure to radon decay products, the increases observed in this study raise important questions about the increased risk to nonsmokers due to the presence of passive cigarette smoke. Most studies have focused on the increased risk to smokers related to combined effects of cigarette smoke and radon decay products. We suggest that further studies also consider the possibility of increased risk to nonsmokers in the home of a smoker. The risk to occupants of a home with radon at EPA's guideline level of 4 pCi/l could be quite different in the home of a smoker in comparison to a home with no smokers.

The question also arises about the increased risk to smokers. Since cigarette smoke significantly increases Working Levels and percent equilibrium, then wherever a person is smoking these parameters are affected. That is to say that smokers create an environment around them of increased Working Levels wherever they are. Therefore, smokers not only inhale cigarette smoke, with corresponding risks, but also they inhale an atmosphere of increased radon decay product concentrations at the same time. Perhaps this is a contributing factor to the increased risk of lung cancer to smokers.

For those who conduct Working Level measurements, these studies also indicate that technicians making such measurements should not smoke. Otherwise, the Working Level readings may reflect smoking habits of the technician, or other occupants of a home, rather than natural Working Levels. These studies also highlighted the need to consider other sources of lung cancer risk in homes, namely the contribution from thoron decay products.

The work described in this paper was not funded by the U.S. Environmental Protection Agency and therefore the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

NEEDS FOR FURTHER STUDY

These studies were intended to demonstrate that passive cigarette smoke affects home occupant's exposures to radon (and thoron) decay products. We understand that increases in aerosol concentration may also reduce the unattached fraction of polonium-218 and that may reduce the intake and retention of decay product alpha energy. We did not measure unattached fractions. We also did not measure aerosol concentrations or particle size distribution. For a better assessment of potential health risks from passive smoke further studies should consider measurements of home ventilation rates, aerosol concentration, particle size distribution, and unattached fractions, as well as radon gas concentration, Working Levels, and percent equilibrium.

REFERENCES

1. National Council on Radiation Protection and Measurements. Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States, Report No. 78, NCRP, Bethesda, Maryland, 1984. 204 pp.

2. National Academy of Sciences. Health Risks of Radon and Other Internally Deposited Alpha-emitters. Committee on the Biological Effects of Ionizing Radiation, BEIR-IV. National Academy Press, Washington, D.C. 1988. 602 pp.

3. U.S. Environmental Protection Agency. A Citizen's Guide to Radon: What It Is and What To About It. OPA - 86 - 004, USEPA, Washington, D.C. 1986. 14 pp.

4. Kabat, G. Lung cancer related to smoking. In: Proceedings of the Twenty-fourth Annual Meeting of the National Council on Radiation Protection and Measurements, Bethesda, Maryland, 1989. p. 65.

5. National Academy of Sciences. Environmental Tobacco Smoke: Measuring Exposures and Assessing Health Effects. National Academy Press, Washington, D.C. 1986.

6. Moeller, D.W. Simple approaches to complex problems. Health Physics Society Newsletter, Vol. XIX, No. 1, Jan. 1991. p. 28.

7. Johnson, R.H., Geiger, E., and Rosario, A. Cigarette smoking increases working level exposures to all occupants of the smoker's home. In: Proceedings of the Fourth Annual Conference of the American Association of Radon Scientists and Technologists. Camp Hill, PA. 1990.

☆U.S. GOVERNMENT PRINTING OFFICE: 1991 - 548 - 187/20556

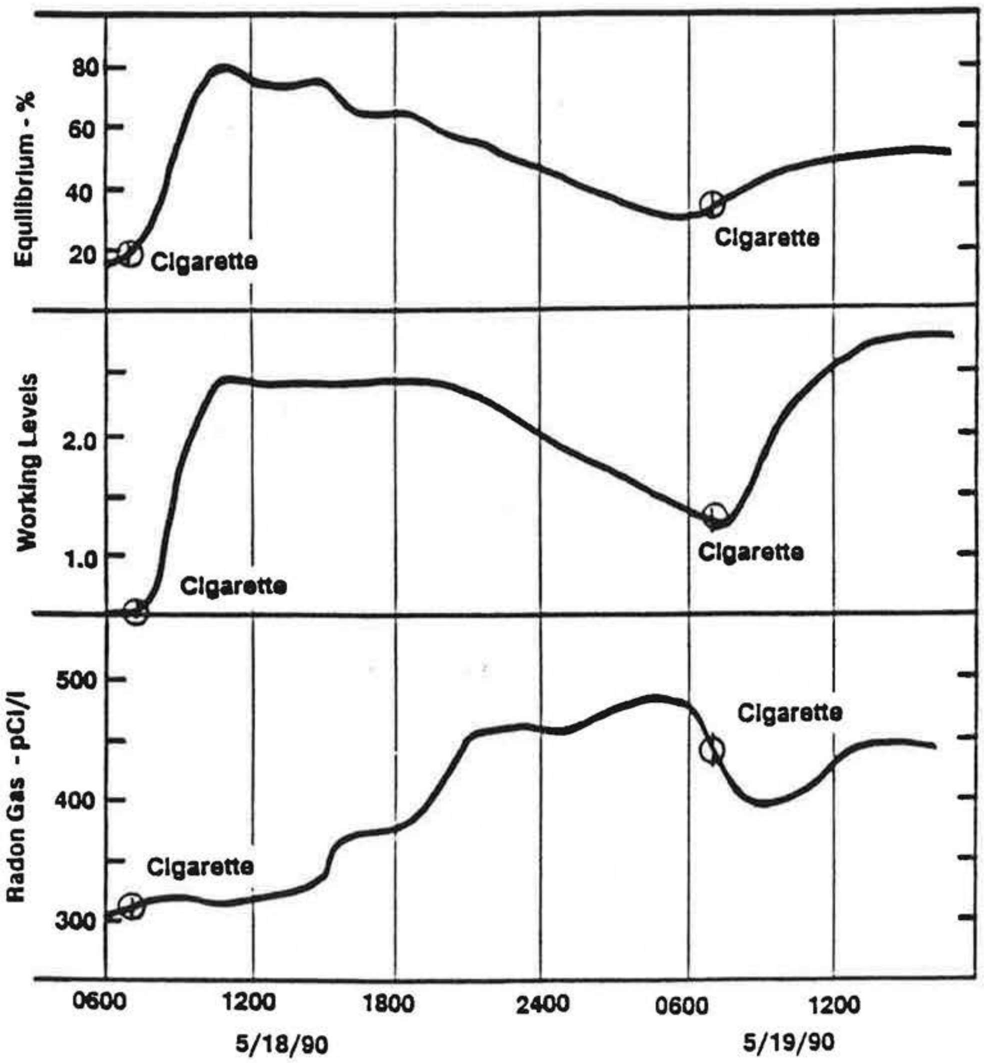


Figure 1. Effect of passive smoke on working levels - Red Chamber, Radon QC

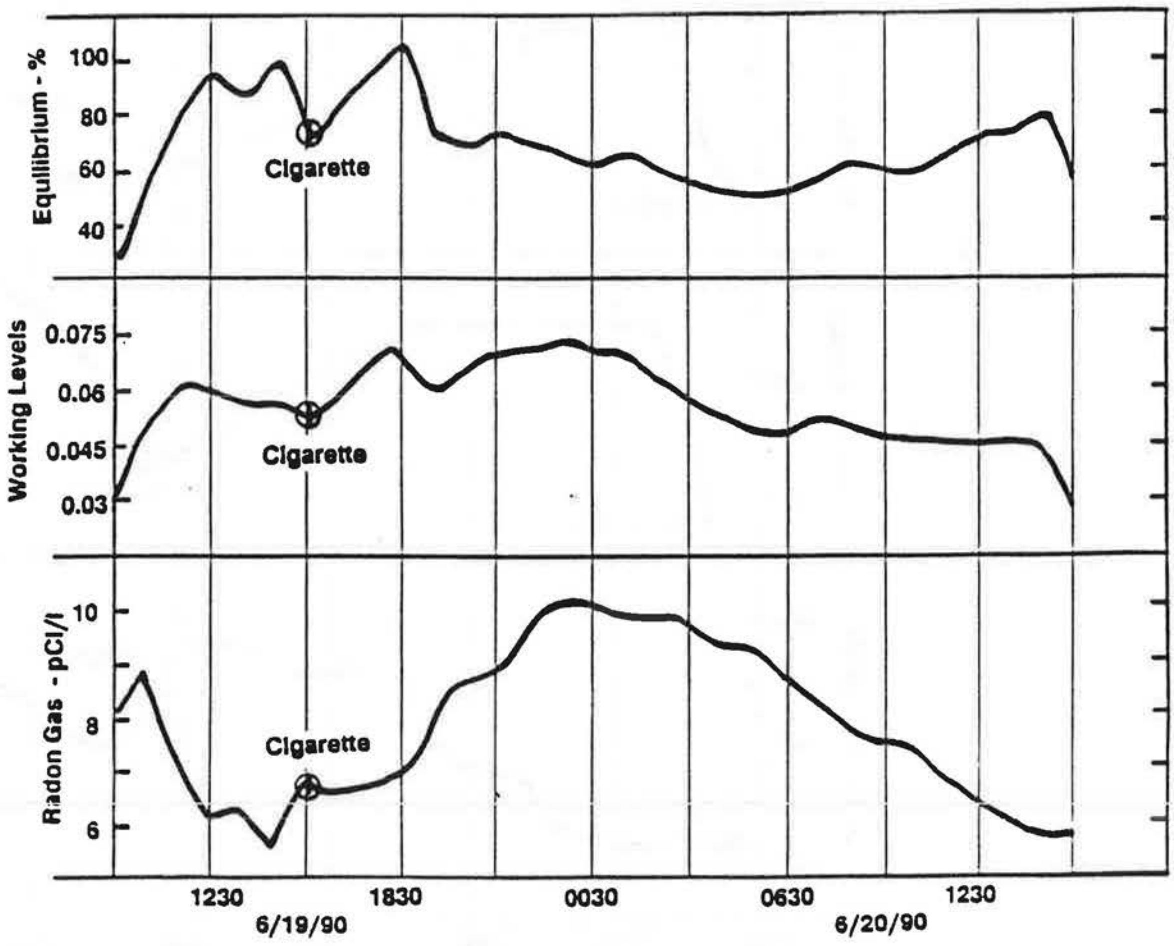


Figure 2. Effect of passive smoke on working levels - Nazareth House

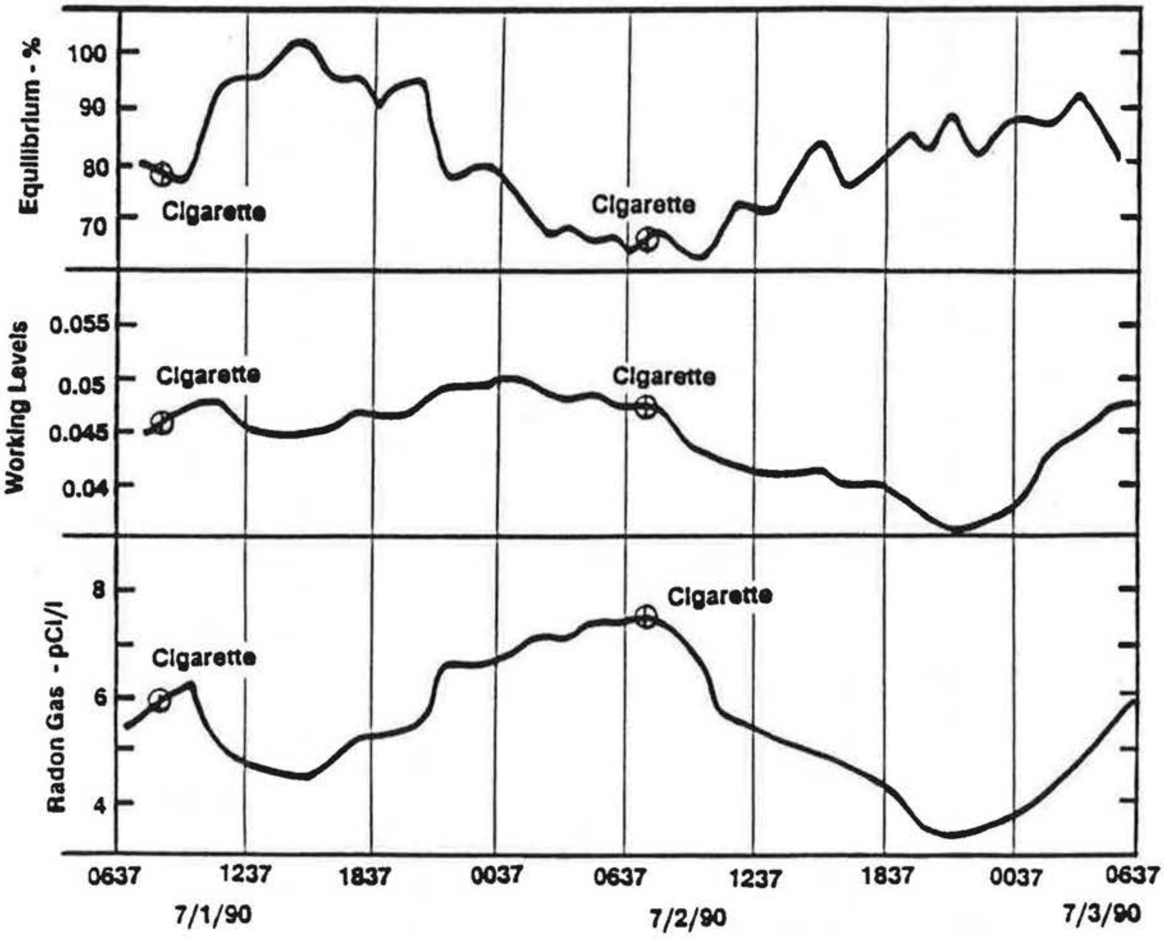


Figure 3. Effect of passive smoke on working levels - Bethlehem House

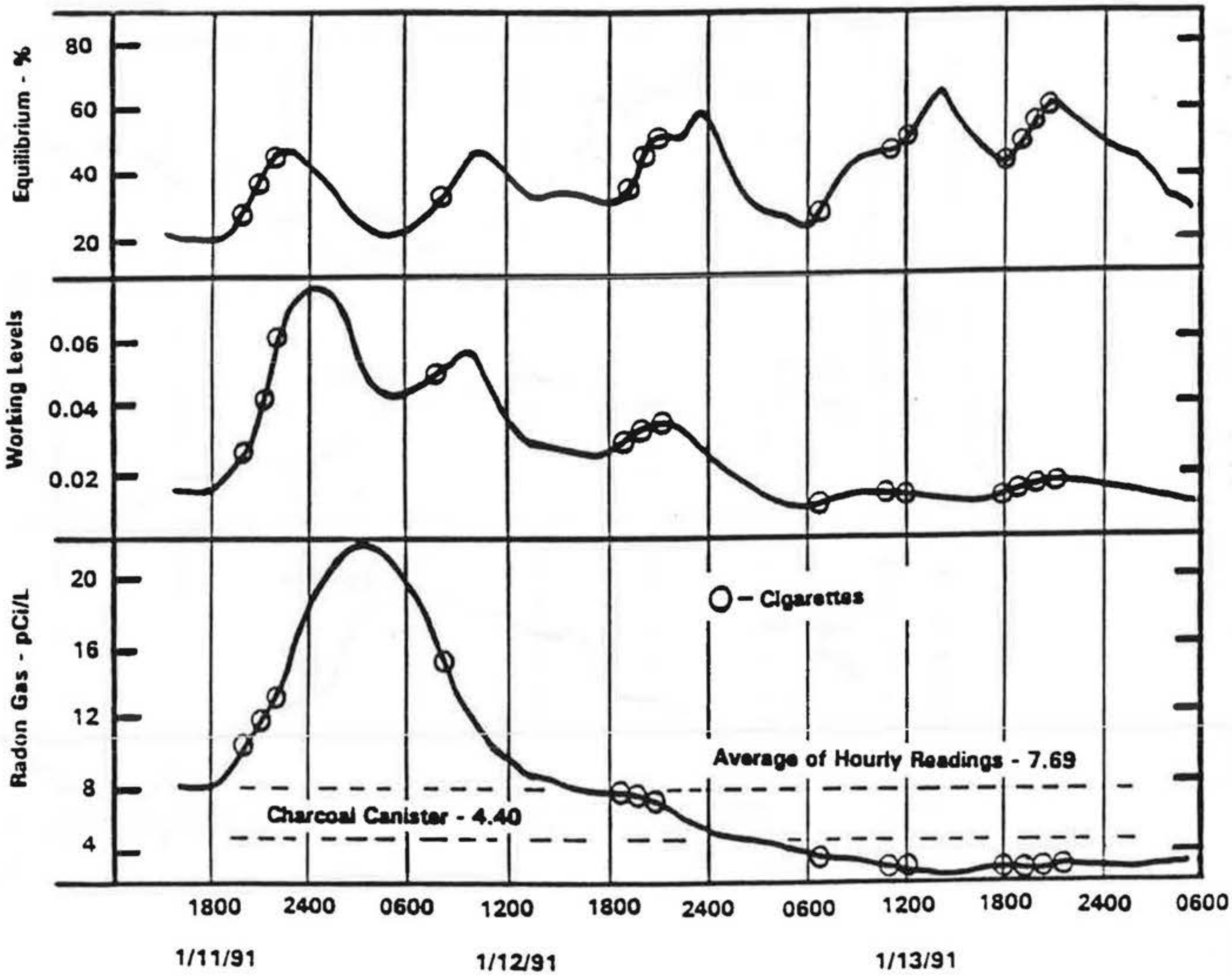


Figure 4. Effect of passive smoke on working levels - Rockville House

126

TABLE 1. EFFECT OF PASSIVE SMOKE ON WORKING LEVELS - RED CHAMBER - RADON QC

	Time	Radon Daughters WL	Radon Gas pCi/L	Equilibrium %
5/18/90	0600	0.45	304	15
	0700	0.44	317	14
	0705	Burned One Cigarette*		
	0800	0.57	318	18
	0900	1.34	323	41
	1000	2.02	319	63
	1100	2.23	314	71
	1200	2.13	320	67
	1300	2.17	328	66
	1400	2.14	322	66
	1500	2.10	328	64
	1600	2.11	382	55
	1700	2.14	374	57
	1800	2.14	376	57
	1900	2.14	378	57
	2000	2.14	432	50
	2100	2.09	455	46
	2200	2.01	457	44
	2300	1.90	455	42
	2400	1.78	457	39
5/19/90	0100	1.67	457	37
	0200	1.58	465	34
	0300	1.48	469	32
	0400	1.39	473	29
	0500	1.30	476	27
	0600	1.22	479	25
	0700	1.14	473	24
	0705	Burned One Cigarette*		
	0800	1.13	409	28
	0900	1.52	397	38
	1000	2.92	398	48
	1100	2.11	410	51
	1200	2.23	423	53
	1300	2.34	442	53
	1400	2.42	440	55
	1500	2.42	450	54
	1600	2.45	451	54

* Marlboro 100 Filter Cigarette

TABLE 2. EFFECT OF PASSIVE SMOKE ON WORKING LEVELS - NAZARETH HOUSE

	Time	Radon Daughters WL	Radon Gas pCi/L	Equilibrium %
6/19/90	0930	0.021	7.43	28
	1030	0.050	8.87	56
	1130	0.058	7.01	82
	1230	0.058	6.13	95
	1330	0.053	6.24	85
	1430	0.054	5.48	99
	1530	0.050	6.86	73
	1530	Burned One Cigarette*		
	1630	0.054	6.59	82
	1730	0.063	6.66	95
	1830	0.069	6.72	103
	1930	0.057	7.77	73
	2030	0.061	8.61	71
	2130	0.066	8.74	76
	2230	0.067	9.59	70
	2330	0.071	10.13	70
6/20/90	0030	0.066	10.16	65
	0130	0.066	9.66	68
	0230	0.060	9.74	62
	0330	0.057	9.66	59
	0430	0.052	9.24	56
	0530	0.049	9.24	53
	0630	0.049	8.70	56
	0730	0.050	8.33	60
	0830	0.050	7.77	64
	0930	0.047	7.48	63
	1030	0.046	7.40	62
	1130	0.047	6.70	70
	1230	0.046	6.24	74
	1330	0.045	6.07	74
	1430	0.046	5.69	81
	1530	0.030	5.74	52

* Marlboro 100 Filter Cigarette

TABLE 3. EFFECT OF PASSIVE SMOKE ON WORKING LEVELS - BETHLEHEM HOUSE

	Time	Radon Daughters WL	Radon Gas pCi/L	Equilibrium %
7/1/90	0537	0.044	5.17	85
	0637	0.044	5.56	79
	0737	0.046	5.66	81
	0837	0.047	6.16	76
	0837	Burned One Cigarette*		
	0937	0.048	6.26	77
	1037	0.050	5.99	83
	1137	0.049	5.14	95
	1237	0.045	4.80	94
	1337	0.045	4.67	96
	1437	0.045	4.48	100
	1537	0.045	4.48	100
	1637	0.045	4.76	95
	1737	0.049	5.14	94
	1837	0.048	5.35	90
	1937	0.048	5.20	92
	2037	0.051	5.40	94
	2137	0.052	6.64	78
	2237	0.051	6.57	78
	2337	0.053	6.64	80
7/2/90	0037	0.053	6.80	78
	0137	0.052	7.00	74
	0237	0.050	7.40	68
	0337	0.050	7.06	71
	0437	0.050	7.42	67
	0537	0.050	7.31	68
	0637	0.048	7.46	64
	0737	0.050	7.41	67
	0737	Burned One Cigarette*		
	0837	0.048	7.30	66
	0937	0.042	6.81	62
	1037	0.041	6.13	67
	1137	0.041	5.48	75
	1237	0.038	5.30	72
	1337	0.038	5.16	74
	1437	0.037	4.84	76
	1537	0.039	4.64	84
	1637	0.035	4.59	76
	1737	0.035	4.47	78

* Marlboro 100 Filter Cigarette

TABLE 4. EFFECT OF PASSIVE SMOKE ON WORKING LEVELS - ROCKVILLE HOUSE

Time	Radon Daughters WL	Radon Gas pCi/L	Equilibrium %	Cigarettes* Burned
1/11/91				
1600	0.016	8.10	20	
1700	0.016	7.83	20	
1800	0.016	7.64	21	
1900	0.017	9.00	19	
2000	0.026	10.3	25	1
2100	0.044	11.0	40	3
2200	0.061	13.1	47	3
2300	0.074	14.9	50	
2400	0.077	17.5	44	
1/12/91				
0100	0.076	21.0	36	
0200	0.073	22.2	33	
0300	0.057	22.0	26	
0400	0.044	22.1	20	
0500	0.044	21.5	20	
0600	0.043	20.0	22	
0700	0.042	17.5	24	
0800	0.048	14.7	33	2
0900	0.057	12.9	44	
1000	0.055	11.3	48	
1100	0.048	10.2	47	
1200	0.036	9.40	39	
1300	0.028	9.20	31	
1400	0.029	8.49	34	
1500	0.026	7.99	33	
1600	0.027	7.84	35	
1700	0.026	7.75	33	
1800	0.023	7.85	29	
1900	0.027	7.97	33	3
2000	0.034	7.50	45	3
2100	0.035	7.00	52	2
2200	0.033	6.49	51	
2300	0.030	5.42	56	
2400	0.028	4.83	58	

* Winston 100 Filter Cigarette