American Academy of Pediatrics

Committee on Environmental Hazards

Radon Exposure: A Hazard to Children

BACKGROUND

In December 1984, a construction engineer who lived in Boyertown, PA, triggered radiation monitors while entering the Limerick nuclear power plant near Philadelphia. He had not been contaminated by radioactive materials at the plant; therefore, his home in nearby Berks County was tested. The concentration of radon gas there was 2,700 pCi/L of air, a level much higher than had ever been measured in a residence in the United States. In January, the engineer, his wife, and their two small children were advised to leave the home immediately. The family had been exposed to radiation levels more than 50 times the annual occupational limit for uranium miners. Radon levels in an adjacent house were low but were extremely high in other nearby houses. This region of the country, known as the Reading Prong, which encompasses parts of Pennsylvania, New Jersey, and New York, has geologic deposits of low-grade uranium ore.

Radon gas, a relatively common natural indoor air pollutant is a radioactive decay product of uranium. Radon and its decay products have been shown to increase the risk of lung cancer in underground miners. More recently, radon has been recognized to be widespread in homes in the United States. An estimated 13,000 lung cancer deaths per year may be attributed to residential exposure to radon gas.[1] In this statement the hazards of exposure to radon and its decay products, known as radon progeny or radon daughters, are reviewed.

NATURE AND SOURCES OF RADON

Radon is a colorless, odorless, inert radioactive gas. It arises from radioactive decay of naturally occurring radium-226. It has a half-life of 3.8 days. Radon gas undergoes spontaneous decay to produce radon progeny—isotopes of polonium, bismuth, and lead. These progeny, rather than radon itself, are responsible for most of the adverse health effects of radon exposure. The progeny of greatest interest for health are polonium-218 and polonium-214. Two physical features of the radon progeny are major determinants of their health effects. First, the progeny are minute, solid particles, not gases. Therefore, after inhalation they are retained in the lungs and tracheobronchial tree and are not dispersed throughout the body because of their rapid radioactive decay. Second, the radiation emitted from the progeny is α-radiation, which penetrates a distance of no more than 70 μm into tissue. For these two reasons, the cancers produced by radon exposure are limited to the respiratory tract and do not involve bone marrow, thyroid, or other organ systems. The total radioactivity is absorbed by the tissues of one organ and therefore results in a much more concentrated exposure than if the isotope were distributed throughout the body.

There are several sources of radon: soil, water, building materials, and natural gas. Radon in the soil on which a home is built is the most common reason for increased indoor radon levels. Radon diffuses through rocks and soil and can accumulate in tiny subsurface air pockets. From there, it is pulled into houses through cracks and pores in the foundation by pressure differences created by the rising of warm air.

Radium, which produces the radon, is at highest concentration in uranium deposits and in some granite and shale deposits and phosphate-containing soils. The construction of tight, energy-efficient homes with increased weatherstripping can exacerbate an existing radon problem by reducing the number of home air exchanges per hour, thereby increasing indoor concentrations of radon. It is important to recognize that radon has been found in homes throughout the United States. Further-

The recommendations in this statement do not indicate an exclusive course of treatment or procedure to be followed. Variations, taking into account individual circumstances, may be appropriate.

PEDIATRICS (ISSN 0031 4005). Copyright © 1989 by the American Academy of Pediatrics.

Copyright © 2001 All Rights Reserved

more, the distribution is uneven. Even in extremely contaminated areas, adjacent houses will vary greatly in their radon concentrations.

Concentrations of radon are usually expressed in picocuries per liter. A measurement of 1 pCi/L indicates that approximately 2 radon atoms are disintegrating each minute in 1 L of air. The "working level" is the unit of measurement for potential α-energy from radon progeny. In a typical house, 1 working level is associated with 200 pCi/L of radon.[2] The working level is defined as any combination of radon daughters (^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po) in 1 L of air that results in the ultimate emission of 1.3×10^5 million electron volts of α-energy from the total decay of each daughter.[3] Exposure to radon progeny is expressed in terms of a working level month which is based on a 170-hour working month for miners. To calculate the working level months per year, the number of hours of exposure per year is divided by 170 and the result is multiplied by the average working level. For home exposure, the working level months are equal to the number of working levels multiplied by 38 (assuming 75% of the hours are spent in the home).

The average national exposure to radon and its progeny is estimated to be approximately 0.2 working level months per year or one tenth of the level allowed in mining.[4] Existing surveys, however, are not random samples of the United States and few are random samples of a local area.

The evidence linking radon exposure to lung cancer comes primarily from studies of undergound miners. Numerous studies in different areas of the world have shown that underground miners exposed to radon have an increased risk of lung cancer.[6-12] Additionally, epidemiologic studies in Sweden have suggested that increased exposure to radon in homes is associated with increased lung cancer mortality.[13,14] It is important to recognize that radon exposures in some homes have been as great as those in certain mines.

Several studies have documented a synergistic effect between radon and cigarette smoking in the development of lung cancer.[13,14] Although the precise nature of the relationship is unknown, the effects appear to be nearly multiplicative.[1]

In early 1988, a committee of the National Academy of Sciences released a report concerning their estimates of the risks from exposure to radon.[1] The risk depends on the magnitude of the cumulative radon exposure, the age at which it occurred, and time since exposure. It is also a function of the lung cancer risk in the absence of radon exposure. Thus, the risk for smokers is estimated to be much greater than the risk for nonsmokers. In Fig 1, the ratio of lifetime risks for lung cancer mortality for life exposure of US men to radon progeny at constant rates of annual exposure is shown. It can be seen that lifetime exposure to 1 working level month per year is estimated to increase the risk of lung cancer death by approximately 1.5 more than the rate for men in populations having the current prevalence of cigarette smoking. In these cases, most of the risk is in smokers, in whom the risk is many times greater than in nonsmokers.

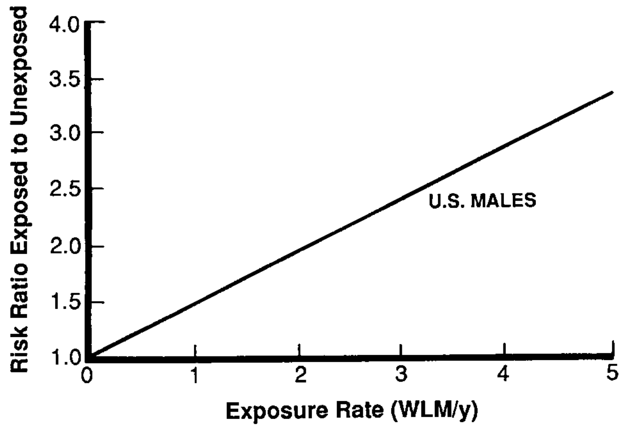

Fig 1. Risk of lung cancer death. WLM/y, working level month per year.

It is important to note that in no studies has a child's risk of lung cancer developing in adulthood after exposure to radon in the home environment been examined. It has yet to be determined whether the risks of lung cancer derived from studies of men who were occupationally exposed to radon in the underground mines apply to children. For all of the estimated risks mentioned previously, it was assumed that age at exposure does not affect the risk associated with radon daughter exposure. However, it is plausible that exposure before age 20 years might have greater effects than exposure at later ages. Evidence for this possibility comes from the fact that Japanese atomic bomb survivors exposed before 20 years of age had higher relative risks of radiation-induced cancers than those exposed later in life.[15] Until further data are available, it seems prudent to assume that the risks to children are at least as large as those determined in occupational studies.

There is no existing standard for indoor radon for residential houses in the United States. However, the US Environmental Protection Agency and the US Department of Health and Human Services have proposed guidelines suggesting that indoor radon levels be kept at less than 4 pCi/L. In Fig 2 various radon levels and comparable health risks from smoking cigarettes are shown. Exposure to radon is assumed to occur throughout a lifetime of 70 years.[16]

Radon can be measured by two methods: (1) α-track detectors can be placed in the home for at

Copyright © 2001 All Rights Reserved

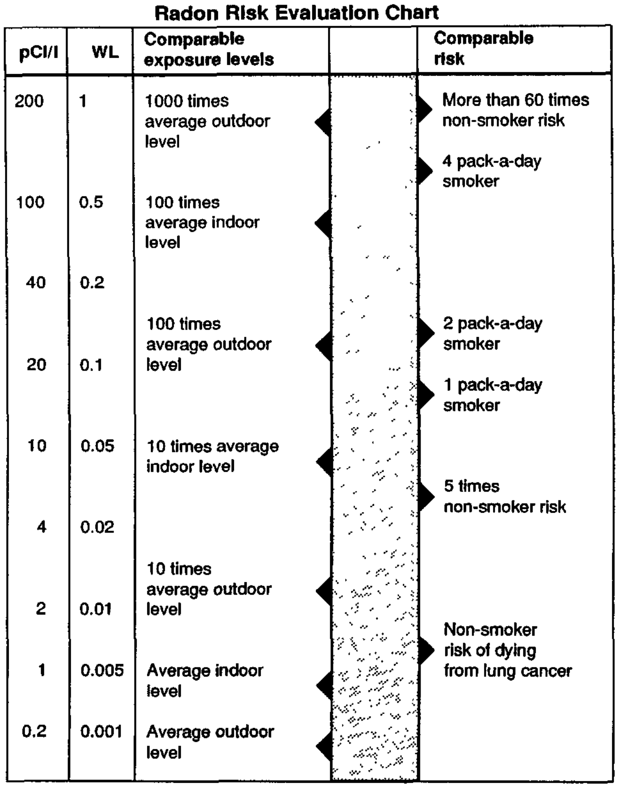

Fig 2. Radon risk evaluation chart. WL, working level.

least 3 months to obtain a time-integrated measurement of the radon level or (2) charcoal canisters can be exposed to the air in the home for four days. These canisters are extremely sensitive and humidity dependent but are appropriate as a screening device. However, the α-track detector, used throughout a long period, gives a better estimate of exposure than the charcoal canister because the former devices averages out daily fluctuations in indoor radon levels.

Radon exposure can be reduced by increasing house ventilation[17] and by reducing the influx of radon to the house. Several methods of doing this include sealing off cracks through which radon can enter foundations, creating negative pressure under the basement floor, and prohibiting the use of building materials containing excessive radium.

RECOMMENDATIONS FOR PEDIATRICIANS

1. Pediatricians should be aware that radon exposures are greater in some geographic areas than others but that radon may be present in any home in any area. Information about local radon levels can be obtained from state health departments or local environmental health authorities. Radon levels in the home may be due to multiple factors, not necessarily just the composition of the ground under the home.

2. Pediatricians should be aware of, and warn their patients about, the multiplicative effects of radon and cigarette smoke on risk of lung cancer. Pediatricians should urge parents not to smoke in the home if children are present. Because the major cause of lung cancer is cigarette smoking, pediatricians should also counsel children not to smoke cigarettes.

3. Pediatricians should alert parents to the educational resources available about radon. Such resources include the Environmental Protection Agency/Centers for Disease Control *Citizen's Guide to Radon*, which may be obtained by writing to the Environmental Protection Agency regional offices.

4. If parents want to test for radon in the home, they should find a reputable company, because some companies that offer the service may not give reliable results. This is a rapidly evolving practice, and parents should check with the Environmental Protection Agency regional offices for the most current listing of companies that have completed the Radon and Radon Progeny Measurement Proficiency Program. Appended to this statement are the phone numbers for each of these offices.

5. Pediatricians should warn families living in homes with radon levels greater than 4 pCi/L (0.02 working level) that they should undertake action to decrease the level of radon in the home based on the Environmental Protection Agency/Centers for Disease Control action timetable. A booklet entitled *Radon Reduction Methods: A Homeowner's Guide* has been published by the Environmental Protection Agency to describe various methods that may reduce the level of radon in the home. These methods require the services of a professional contractor who is experienced in radon-reduction procedures. Free copies are available through each of the Environmental Protection Agency's regional offices listed in the Appendix.

COMMITTEE ON ENVIRNOMENTAL HAZARDS, 1987–1988
Richard J. Jackson, MD, Chairman
John H. DiLiberti, MD
Philip J. Landrigan, MD
Gerald Nathenson, MD
Herbert L. Needleman, MD

Liaison Representatives
Audrey K, Brown, MD (Section on Oncology/Hematology)
Ruth A. Etzel, MD (Centers for Disease Control)
Henry Falk, MD (Centers for Disease Control)
Robert W. Miller, MD (National Cancer Institute)
Walter Rogan, MD (National Institute of Environmental Health Sciences)

Copyright © 2001 All Rights Reserved

Appendix: Regional Radon Contacts

Region 1 (Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island):
USEPA
JFK Federal Building
Boston, MA 02203
(617) 565-3715

Region 2 (New York, New Jersey):
USEPA
26 Federal Plaza
New York, NY 10278
(800) 458-1158 (NY)
(800) 648-0394 (NJ)

Region 3 (Pennsylvania, Delaware, Maryland, District of Columbia, West Virginia, Virginia):
USEPA
841 Chestnut St
Philadelphia, PA 19107
(215) 369-3590

Region 4 (Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Florida):
USEPA
345 Courtland St, NE
Atlanta, GA 30365
(404) 347-3907

Region 5 (Michigan, Ohio, Indiana, Illinois, Wisconsin, Minnesota):
USEPA
230 South Dearborn St
Chicago, IL 60604
(312) 353-2072

Region 6 (Arkansas, Louisiana, Oklahoma, Texas, New Mexico):
USEPA
1201 Elm St
Dallas, TX 75270
(214) 655-7208

Region 7 (Iowa, Missouri, Kansas, Nebraska):
USEPA
726 Minnesota Ave
Kansas City, KS 66101
(913) 236-2893

Region 8 (North Dakota, South Dakota, Montana, Wyoming, Colorado, Utah):
USEPA
Ste 1300
1 Denver Place
999 18th St
Denver, CO 80202
(303) 293-1709

Region 9 (California, Arizona, Nevada, Hawaii):
USEPA
215 Fremont St
San Francisco, CA 94105
(415) 974-8076

Region 10 (Washington, Oregon, Idaho, Alaska):
USEPA
1200 Sixth Ave
Seattle, WA 98101
(206) 442-0218

REFERENCES

1. Committee on the Biological Effects of Ionizing Radiations, National Research Council: *Health Risks of Radon and Other Internally Deposited Alpha-Emitters.* Washington, DC, National Academy Press, 1988
2. *Radon Reference Manual.* Washington, DC, Environmental Protection Agency, 1986
3. Eichholz GG: *Environmental Aspects of Nuclear Power.* Ann Arbor, MI, Ann Arbor Science Publishers, Inc, 1982, p 509
4. Nero AV, Schwehr MB, Nazaroff WW, et al: Distribution of airborne radon-222 concentrations in U.S. homes. *Science* 1986;234:992–997
5. Deleted in proof
6. Lundin FE, Wagoner JK, Archer VE: Radon daughter exposure and respiratory cancer, in *Quantitative and Temporal Aspects.* US Department of Health, Education, and Welfare (USDHEW), National Institute for Occupational Safety and Health (NIOSH), National Institute of Environmental Health Sciences (NIEHS), joint monograph, No. 1., Government Printing Office, 1971, pp 111–113
7. Waxweiler RJ, Roscoe RJ, Archer VE, et al: Mortality follow-up through 1977 of the white underground miners cohort examined by the U.S. Public Health Service, in Gomez, M (ed): *Radiation Hazards in Mining.* New York, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc, 1981, pp 823–830
8. Sevc J, Kunz E, Placek V: Lung cancer in uranium miners and long-term exposure to radon daughter products. *Health Phys* 1976;30:433–437
9. Kunz E, Sevc, J, Placek V: Lung cancer mortality in uranium miners (methodological aspects). *Health Phys* 1978;35:579–580
10. Muller J, Wheeler WC, Gentleman JF, et al: Study of mortality of Ontario Miners, in Stocker H (ed): *Proceedings of the International Conference,* vol 1: *Occupational Radiation Safety in Mining.* Toronto, Canadian Nuclear Association, 1985, pp 335–343
11. Radford EP, Renard KG: Lung cancer in Swedish iron miners exposed to low doses of radon daughters. *N Engl J Med* 1984;310:1485–1494
12. Morrison HI, Semenciw RM, Mao Y, et al: Lung cancer mortality and radiation exposure among the Newfoundland fluorspar miners, in Stocker H (ed): *Proceedings of the International Conference,* vol 1: *Occupational Radiation Safety in Mining.* Toronto, Canadian Nuclear Association, 1985, pp 365–368
13. Axelson O, Edling C, Kling H: Lung cancer and residency—A case referent study on the possible impact of exposure to radon and its daughters in dwellings. *Scand J Work Environ Health* 1979;5:10–15
14. Edling C, Wingren G, Axelson O: Radon daughter exposure in dwellings and lung cancer, in Berglung B, Lindall T, Sundell J (eds): *Indoor Air,* vol 2: *Radon Passive Smoking Particulates and Housing Epidemiology.* Stockholm, Swedish Council for Building Research, 1984, pp 29–34
15. Shimizu Y, Kato H, Schull WJ, et al: *Life Span Study,* report 11, part 2: *Cancer Mortality in the Years 1950–85 Based on the Recently Revised Doses (D586).* Radiation Effects Research Foundation technical report 5-88, 1988
16. Environmental Protection Agency/Centers for Disease Control: *A Citizen's Guide to Radon: What It Is and What To Do About It.* Government Printing Office, 1986
17. Council on Scientific Affairs: Radon in homes. *JAMA* 1987;258:668–672

Copyright © 2001 All Rights Reserved