that any errors will be in favor of protecting workers and the general public from environmental hazards. □

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Acknowledgments

I would like to thank the following individuals for their useful comments on earlier drafts of this document: Kyle Steenland, Michael Attfield, David Dankovic, Stan Dawson, Jon Kogut, Steve Bayard, Bob Park, Eileen Kuempel, John Bailer, and William Pepelko.

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The Ebb and Flow of Radon

We are approaching an anniversary of sorts—radon became a public health issue almost 15 years ago. As those of us know who have been involved in radon research, levels of radon vary over time within homes, mirroring to some extent the fluctuation of the public's interest in the problem. Even in states with aggressive radon programs, such as my own New Jersey, we know that while much has been accomplished, much is left to be done.

Defining the Problem

In late 1984, Stanley Watras, a resident of Boyertown, Penn, employed at the Limerick Nuclear Generating Station, moved the issue of exposure to radon gas out of the realm of mines and contaminated sites and into the forefront of environmental health issues confronting the public.[1] Watras was an unlikely initiator of this transition. An electrical engineer, he worked in areas of the Limerick plant where he should not have come into contact with radioactive materials, but he nevertheless triggered contamination alarms when exiting the plant at the end of the workday. Once Watras established that he could trigger these alarms when arriving for work, Limerick and Pennsylvania state officials were able to identify radon decay products adhering to his clothing as the offending contaminants and the Watras home as the source.

Radon 222, the immediate decay product of radium 226, is part of the naturally occurring uranium decay series beginning with uranium 238 and ending with stable lead 206. Experience with underground miners and radium dial painters has shown it to be a human carcinogen, increasing the incidence of lung cancer in those exposed.[2] Because it is an inert gas with a 3.8-day half-life, radon moves freely in soils of suitable porosity under the influence of relatively small pressure gradients. The decay products of radon are isotopes of polonium, bismuth, and lead. Once created by the decay of radon, these metals can electrostatically collect on dust particles suspended in the air and, if these particles are inhaled and attach to lung tissue, produce high local radiation dose. Until the mid-1980s, assessing human exposure to radon and its decay products was largely the province of occupational hygienists employed in the mining industry and health physicists involved in remediating homes

Editor's Note. Please see related article by Alavanja et al. (p 1042) in this issue.

built on uranium-rich tailings from mining or ore-processing operations.

Shortly before Christmas, Watras and his family were advised to vacate their home because it harbored radon decay product levels exceeding those to which uranium miners could be occupationally exposed. The Watras family heeded that advice, and the US Environmental Protection Agency (EPA), with support from Pennsylvania state officials, turned the home into a laboratory for measurements of radon and radon decay products and evaluation of remedial measures. After many months, the radon concentration was reduced to acceptable levels and the family was able to return to their home. Unfortunately, Watras' radon problem did not prove to be an isolated incident.

At first, the problem appeared to be confined to the relatively limited geology of weathered granite characteristic of a formation known as the Reading Prong and extending roughly northeastward from Pennsylvania through northwestern New Jersey and into lower New York state.[2] Further, it appeared to be sporadic. A home with unacceptable radon levels might be the only one in its neighborhood or one of only a few affected in that neighborhood. Thus, it was initially anticipated that the indoor radon problem would be generally limited to a small minority of homes with a very few high-level outliers. Unfortunately, studies would show that the problem was not confined simply to structures built on or near weathered granite.[3] Unacceptably high indoor levels would be discovered to be associated with limestone, shale, sandstone, and a variety of clays.[4] Public health officials, even armed with extensive geological information for a given area, found it virtually impossible to predict radon levels in individual homes. In addition to local geology, home style, construction details, and even usage patterns were found to significantly affect indoor radon levels.[5]

Public Health Response

As knowledge grew that the radon problem was more complex and widespread than originally anticipated, the EPA offered guidance on "unacceptably high" levels of radon and implemented a national radon proficiency testing program to support a fledgling testing industry.[6,7] The guidance offered by the EPA had its roots in advice the agency had given to New Jersey for its radium-contaminated residential sites in Montclair, Glen Ridge, and West Orange and to Florida for homes constructed in phosphate mining areas.[8] The EPA concluded that a concentration of 0.02 working levels of radon decay products, under assumed average conditions equivalent to 4 picocuries per liter (4 pCi/L), was achievable using existing remedial technology.[9] A 1-in-1 000 000 health-based standard was not achievable, because it would have to be less than the average outdoor concentration of radon, about 0.4 pCi/L.

The development of reliable and cost-effective remediation techniques received an unexpected impetus with the identification of the first "radon cluster" in New Jersey. Bernard Cohen at the University of Pittsburgh advised of the discovery of 2 homes in a small housing development in rural Clinton, New Jersey, with very high radon levels (B. L. Cohen, oral communication, March 1986). Cohen had been conducting his own research into the national distribution of indoor radon. In reviewing counting data he realized that 2 homes with levels above 200 pCi/L were virtually neighbors. Eventually, studies showed that of the 124 homes in the development, all but 5 exceeded the 4 pCi/L guidance level for remediation. Some 40 of the homes exceeded 200 pCi/L, and 5 were above 1000 pCi/L.[10]

The EPA's and New Jersey's earlier experiences were brought to bear on this small community for the purpose of developing procedures that could be used to remediate these homes and others elsewhere in the United States. Eventually, all affected homes were successfully remediated, and, more importantly, proven remedial procedures emerged that could be applied in virtually all home construction.[10]

By 1987, most states were aware of the radon problem and had in place or were developing programs to educate the public on what should be done to reduce the risk of lung cancer caused by radon, a risk second only to that posed by cigarette smoking.[11] In 1988 the National Academy of Sciences' National Research Council had issued *Biological Effects of Ionizing Radiation [BIER] IV: Health Risks of Radon and Other Internally Deposited Alpha-Emitters* documenting the mainstream scientific view of the significant risk posed by radon, scientifically justifying the EPA's national radon program.[12]

Were there responsible critics? Certainly. Bernard Cohen's papers questioned whether the available health and radon distribution data supported the EPA's risk estimates.[13–15] Leonard Cole questioned whether the expenditures that would be needed to bring the nation's housing stock down to below 4 pCi/L could be justified and whether the agencies that worked on the radon problem served their own interests or those of the public.[16] Supporters of the EPA's program countered by citing the inherent limitations of retrospective health studies, the wealth of occupational data on miners, the fact that cumulative residential exposures extended well into the dose range of miners, and the high societal cost of treating lung cancer.[17]

Despite questioning, the risk estimates have stood the test of time. Although they have been refined since 1984, the mainstream scientific community has remained firm in its support for reducing residential exposure to radon, and the original 4 pCi/L remedial action guidance level remains unchanged. *BIER VI: Health Effects of Exposure to Radon* is now available and indicates that nationally from 3000 to 32 000 lung cancers per year may be caused by radon.[18]

Where Do We Go From Here?

It has been almost 15 years since Stanley Watras moved his family out of his radon-contaminated home. A majority of knowledgeable scientists and public health officials believe that residential exposure to radon contributes to between 3000 and 32 000 lung cancer cases per year in the United States. Reliable, commercial testing and remediation procedures are available at reasonable cost (testing: $25–$250; most remediation: $800–$2000).[19] Promising new epidemiological research, reported by Alavanja et al. in this issue, has used improved methods for assessing exposure, demonstrating consistency of odds ratio estimates with some earlier studies and documenting significant improvement in determining dose retrospectively.[20]

A question that the study by Alavanja et al. may raise is whether improved radon dosimetry warrants retesting of homes that were previously tested and found to have acceptable levels. If the original test was conducted according to the EPA or state protocols, the answer to this question is, fortunately, no. Irrespective of the test method, sufficient conservatism is built into the test procedure to ensure that homes with an average yearly concentration above the guidance level of 4 pCi/L will be identified, enabling their owners to initiate remedial action.

Regrettably, we know that less than half of the vulnerable housing stock in the United States has been tested for radon. Most testing occurs at the time of sale, as protection primarily for financial interests. While unfortunate, this is also understandable behavior from a public being bombarded daily by the media with the environmental hazard of the moment, supported by experts touting its immediacy and lethality. Most of these hazards will even have an identifiable villain in the form of an industry, the military, or a lax government agency.

As environmental issues ebb and flow around us, our message to the public must be clear: If you haven't already tested for radon, do so now. If your indoor radon level exceeds the guidance level, remediate. If you have remediated, maintain your system properly and seek advice from local and state health officials as to how frequently retesting is warranted to ensure continued acceptable levels.

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Elimination and Reintroduction of a Sexually Transmitted Disease: Lessons to Be Learned?

At a time when the reported incidence of most sexually transmitted diseases (STDs) in the United States is on the decline,[1] the annual incidence of reported primary and secondary syphilis is at its lowest level since World War II,[1] and the Centers for Disease Control and Prevention are initiating a campaign to eliminate syphilis from the United States,[2] the article by Williams et al.,[3] published in this issue of the journal, points to several rather disturbing patterns and trends and offers some important lessons.

The article by Williams et al.[3] is one of many that report on increases in unsafe sexual behaviors among men who have sex with men—a potentially alarming behavioral change. In San Francisco, Calif, the proportion of surveyed men who reported having had anal sex with men increased from 57.6% in 1994 to 61.2% in 1997. Among this group, the proportion reporting "always" using condoms declined from 69.6% in 1994 to 60.8% in 1997, and the proportion of men who reported having had multiple male sex partners and unprotected anal intercourse increased from 23.6% in 1994 to 33.3% in 1997.[4] Other researchers have documented similar increases in unsafe sexual behaviors among men who have sex with men, in response to perceived recent advances in therapeutic options.[5,6,7]

Aggregate increases in unsafe behavior among gay men may result from a number of factors, including the introduction of new cohorts of younger men into the sexually active population; the existence of gaps in the coverage of preventive interventions, particularly among ethnic minorities; and relapse into unsafe behaviors among those who had previously adopted safer practices. Available data support all 3 of these hypotheses: researchers have documented increases in unsafe sexual behavior among young gay men,[8,9] as well as disproportionately higher proportions of ethnic minorities among men who engage in risky homosexual behaviors[10,11] and reductions in safer sex practices because of the perception that AIDS is no longer as big a threat as it used to be[7] (R. Y. Barrow et al., unpublished data, 1999).

In several cities, including Seattle, Wash, increases in unsafe sexual behaviors among men who have sex with men have been associated with increased incidence and/or prevalence of one or more STDs, including HIV infections. In Chicago, Ill, comparisons of the demographics of primary and secondary syphilis cases reported in 1998 with those reported in 1997 revealed that in 1998, men who have sex with men emerged as an important factor for syphilis transmission, changing the epidemiology and demographics of primary and secondary syphilis in this city (C. A. Ciesielski, H. A. Beidinger, unpublished data, 1999). In San Francisco, the increases in unsafe sexual behaviors among men who have sex with men, described above, were accompanied by

Editor's Note. Please see related brief by Williams et al. (p 1093) in this issue.