

Table 5.2 Anomalous NURE Values for Indoor Radon Cluster Areas and Percentage of Homes above 4, 20, and 200 pCi/l Based on Screening Measurements

Location	NUR eU in ppm*	Percentage greater than 4 pCi/l	Percentage greater than 20 pCi/l	Percentage greater than 200 pCi/l
Clinton	10	96	80	35
Montgomery	9	67	27	7
Ewing	8	78	40	5
Princeton	9	75	28	2
Bethlehem	7	75	35	11
Hampton	11	100	64	14
Bernardsville	9	87	45	9
Mansfield	10	88	65	7
Washington	10	87	57	13

Source: Meussig, 1988.

*Peak values for the anomaly in the NURE area.

Unfortunately, NURE data have serious limitations. The technique is very costly. And most existing NURE data employed wider spacing of flights than is optimal for locating radon hot spots. NURE data are also limited to the first foot of soil. However, radioactive bedrock or a radium source may lie at deeper levels (Meussig, 1988).

Geological Investigations for Hot Areas

Another approach for finding hot areas involves the search for geologic formations and soil features known to harbor high radon levels, such as fissures, faults, and the boundaries between geological formations. Local geological features can be reconnoitered using geochemical analysis and radon soil sampling to identify areas worth further investigation (Reimer et al., 1991). A comprehensive method for county-scale radon mapping using such techniques combined with indoor radon testing has been developed by Gunderson and her colleagues at the U.S. Geological Survey (Gunderson et al., 1988). In a study of Montgomery County, Maryland, the researchers combined hundreds of measurements of radon in soil gas and equivalent uranium in soils from across the county with permeability data and voluntarily reported private indoor radon test results. The different rock units in the county were then outlined on a map and rated for either low, medium, or high radon potential.⁹

As with previously discussed efforts at mapping radon potential, there are serious limitations of this approach for making real estate purchase decisions, radon-resistant building standard requirements, or even individual testing decisions. These limitations are evident in the researchers' own disclaimers that "the map should not be used as a sole source for predicting indoor radon levels," that a low rating "does not mean that radon will not be found in these areas, but that the radon potential is low relative to the rest of Montgomery County," and that "no area of the county is free from the potential for indoor radon levels greater than the U.S. EPA remediation level of 4 pCi/l." While calling attention to the overall radon threat, as a predictive tool, little certainty is added by this method. Meanwhile, some residents will test and others will not, some property values will be deflated and others enhanced, and the safety of some areas will be demeaned while others are enhanced, perhaps falsely.

In sum, neither NURE nor a local geologic study is likely to find the needle.

Radon in Water

Much as with airborne radon, radon in water also reflects the myth of the Reading Prong. Here the historic association is with New England, where the issue was first discovered, and where the highest values of radon in well water, levels of over a million pCi/l, have been discovered (Hall et al., 1988). Here, we find another sin of omission: the emerging data show that higher levels of radon in water are widely distributed throughout the country (Hess et al., 1985; Horton, 1985). The granitic rock of the Appalachians is rich in uranium and radium, as evidenced in eastern groundwater. In Florida, the high radium content in the phosphate rock causes high water levels of radon. Other higher values may be found scattered throughout the West and upper Midwest (Brookins, 1990). Reminiscent of the ill conceived effort to map radon in air, figure 5.7 shows three ranges of radon for U.S. groundwater (Brookins, 1990).

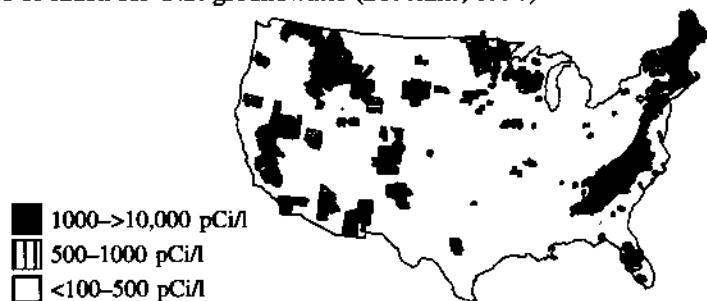


Fig. 5.7 Distribution of radon in groundwater in the United States
(Source: Brookins, 1990, 98)

Table 5.3 demonstrates that homes with individual wells have the highest potential for radon from the water supply. More specifically, perhaps 11 percent of the households with private wells may have radon contributions exceeding the estimated mean air radon concentration (1.5 pCi/l). While the contribution to the overall public health risk from radon in water is small (see chapter 3), for those homes with higher radon concentrations in well water, the water contribution may provide a significant health risk. An analysis of data from public groundwater supplies for the United States further reveals a similar lognormal distribution to that discussed earlier for airborne radon.¹⁰ It is implied that a significant number of groundwater supplies will have radon concentrations much greater than the mean (Nazaroff et al., 1988a).

Table 5.3 Water, Population, and Geometric Mean Values for Radon Concentrations for the United States

Type of water supply	Population Served (%)	Population-weighted geometric mean radon concentration
public surface	49.5	8 pCi/l (300 Bq/m ³)
public groundwater	32.2	140 pCi/l (5,200 Bq/m ³)
private well	18.3	970 pCi/l (36,000 Bq/m ³)

Source: Nazaroff et al., 1988a

Note: 1 pCi/l = 37 Bq/m³.

Similar to the radon distribution in soil gas, the localized geology determines the potential for high waterborne radon levels. Likewise, there may be significant variations in well water radon concentrations from nearby houses; for example, differing well depths may draw water from different rock layers with much different radon concentrations (Clarkin and Brennan, 1991). In every way, despite evidence of its pervasiveness, radon in water has been subjected to myths suggesting that it is bounded and futile efforts to identify hot areas have been undertaken.

Conclusions

We finally understand just how anomalous the Watras discovery was. The average annual radon exposure in the United States is 1.25 pCi/l, and the number of homes with annual average exposures above 4 pCi/l is about 6 percent of the housing stock, or 5.8 million homes. The number of homes with annual average exposure levels greater than 20 pCi/l might be around seventy to eighty thou-

sand, and only a relative few have been found so far. An important question is whether a concerted effort along the lines we have discussed in this section (more NURE-type mapping, detailed county mapping, follow-up on local high radon test results, and so forth) could identify the majority of those hot houses remaining and at what cost? On the other hand, is a massive effort to find these houses warranted if it only eliminates about 0.1–1.0 percent of the overall radon risk when 100 percent implemented? This distribution of radon risk poses a dilemma for radon policy. Clearly shown is that a radon policy focused on hot houses and reducing the highest risk hardly dents the overall public health risk.

In our desperation to find hot houses, hot clusters, and hot regions, we have grasped at many tools, ranging from macroscale to microscale geological investigation, site soil testing, and use of aerial reconnaissance. It is sobering that identified hot spots have been found through serendipity, the accidental anomaly of Stanley Watras being crapped up on his way into work or of the individual homeowner from the Clinton Knolls subdivision who decided to conduct a home radon test. Regional macroscale efforts have been shown to demonstrate little and distort a lot. And while studies of the correlation of indoor radon levels and localized geology provide important information for advancing our understanding of radon dynamics, they provide misleading information, both for radon policy as well as for people considering whether to test, buy, or build a home. Even the most sensitive studies of site-specific radon potential cannot predict house construction, design, and operation variables; geological data are not sufficiently predictive to be protective. Clearly, there is no better alternative for finding the hot needle in the haystack than to test radon levels in all buildings, as discussed in the next chapter. Indeed, EPA has recommended that every house be tested (EPA, 1988b, 1992f) and, in setting a new construction goal of 2 pCi/l, it has made including radon resistance in new homes preferable (see chapter 7). While these orientations conflict with the actual policies in place that depend on hot houses and regional radon boundaries, the very fact that they exist among the mixed messages of radon policy underscores the absurdity of continued efforts at geological and geographic prediction.

Perhaps the most important policy implication from the study of geology and radon is simply this: the radon problem is caused by localized geology; therefore the radon problem cannot be bounded. The myth of the Reading Prong, the idea that certain regions are safe while others are not, is totally false. Even within regions of relatively low indoor radon values, localized concentrations of uranium/radium, soil conditions, weather, house construction and operation factors could provide much higher radon levels in certain homes. And, conversely, even in regions of extremely high radon availability, many houses will be low. Unfortunately, the very attempt to delineate regions into categories (high, moderate, and low risk) sends a double message. To those living in the high-risk region, the message is to test. But the other regions also receive a message: that radon testing is not as urgent. Thus, the exhortation to test based on

the assumption of boundedness, no matter how well qualified and explained, may actually backfire against the goal of protecting public health. As we discuss in chapter 9, the myth of the Reading Prong is a significant misleading influence on public perception of the radon problem. Furthermore, it appears that the EPA believes that the accumulation of ever more detailed grids of indoor radon potential will convince states and the public to take radon more seriously. Carried to its logical conclusion, such a belief might have each acre in the United States classified as to its radon potential. Such a strategy might be a good way to employ geologists, but it is unlikely to provide effective radon policy.

Notes

1. The two studies diverged at higher radon levels. Projections for single family homes with annual average radon concentrations greater than 4 pCi/l were 7 percent (four million homes) for LBL and 6 percent for Cohen; for homes exceeding 8 pCi/l, 1-3 percent for LBL and only 1 percent for Cohen; and for homes with radon values above 20 pCi/l, 0.1-0.2 percent for the LBL study and only 0.02 percent for the Cohen study.

2. For the Terradex data, the arithmetic mean is between 3 and 4 pCi/l, and the data imply that around 2 percent, or 1.6 million homes, may exceed 20 pCi/l.

3. Screening measurements before the new *Citizen's Guide* was issued in 1991 were defined in the lowest livable level of the house, in winter, under closed house conditions, thus including many basements that were not occupied. In 1991, EPA recommended that they be taken in the lowest lived-in level.

4. If one factors in American's high mobility, the chance of any one person receiving a maximum dose from a lifetime of living in a hot house is greatly reduced. For example, if the distribution of radon exposures is corrected to assume that every person moves every seven years to a randomly selected house instead of spending their lifetime in the same building, the projected percentage of the population expected to have annual average lifetime exposures over 4 pCi/l drops to one-tenth the prior estimate (from 6.0-7.0 percent to 0.6 percent) (Nero et al., 1986, 1990). Of course, since some people may not move as often, the actual percentage of people exceeding a lifetime average of 4 pCi/l will lie somewhere between these estimates. Significantly, the overall public health risk is not diminished by mobility, but is just redistributed. As the individual high risk associated with high radon houses is further reduced, a policy based on finding hot houses is even harder to justify.

5. The myth of the Reading Prong was reinforced by the media, as well as by government. For example, a 1986 public presentation on radon by the New Jersey Department of Environmental Protection included color slides of the Reading Prong, even though it was already well known that there was a substantial radon problem outside of the prong. Even the EPA, who also should have known better, kept using the Reading Prong image long after it had been discounted by accumulating data. For example, based on state/EPA screening surveys, the EPA referred to parts of Minnesota and North Dako-

ta as "similar in severity to the Reading Prong" (EPA 1987c). Indeed, there were very few "hot houses" in the region, but there were many houses that were slightly elevated above 4 pCi/l. Testing since 1985 has found elevated radon levels in practically every state. Radon is ubiquitous on the planet.

6. These rock types include carbonaceous black shale, glauconite-bearing sandstones, some fluvial sandstones, phosphorites and phosphatic sediments, chalk, some carbonates, some glacial deposits, bauxite, lignite and some coals, uranium-bearing granites and pegmatites, metamorphic rocks of granitic composition, felsic and alkalic volcanoclastic and pyroclastic volcanic rocks, syenites and carbonatites, and many sheared and faulted rocks (Gunderson et al., 1991).

7. These include marine quartz sands, some shales, siltstones and clays, and some mafic rock (Gunderson et al., 1991).

8. Bismuth-214 counts were converted to equivalent uranium (eU). Anomalies were defined as exceedances of 6 eU compared to the mean statewide value of 2.4 eU.

9. Low potential areas have less than a 40 percent chance that levels of radon greater than 4 pCi/l will be found in a home in the area (based on screening tests in the basement or lowest livable area of the house). A moderate rating has a 50 percent chance of a home being elevated, with 10 percent of the homes exceeding 20 pCi/l. A high rating has a greater than 60 percent chance of a home having elevated radon with as many as 30 percent of the houses greater than 20 pCi/l.

10. The data collected on public groundwater supplies are limited to public supplies serving one thousand or more people (accounting for 86 percent of the public groundwater supplies). Smaller supplies serving fewer people appear to have somewhat higher concentrations (see Nazaroff et al., 1988a).