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# Radon testing in Arkansas homes

*Indoor radon levels may be affected by air exchange rates, age and type of house, and geographic/geologic location*

**By James E. Metzger**

The relatively recent attention paid to the environmental threat of radon exposure in America's homes has its roots in two seemingly unrelated events of the last 20 years. First, the heightened awareness of the general public to the dangers of air and water pollution led to a renewed interest in preserving the health and beauty of America's resources. This includes not only traditional areas of natural enjoyment such as national parks, but also urban environments that experienced degradation from man-made pollutants.

Second, the move toward energy conservation that was impelled by the OPEC cartel's quadrupling of oil prices in 1974-1975 (and subsequent increases in 1979) dramatically affected America's housing stock by creating a new emphasis on "tighter," energy-efficient homes with lower utility costs. While more energy-efficient homes did not create higher radon levels, the conservation movement did focus attention on the issue of air quality in the home.


**About the author**

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One hallmark of the well-designed new home (or the well-executed, retrofitted older home) is the lessening of the air infiltration from outside the structure. New techniques of construction, more consistent application of old and new building techniques, and a surge of new construction materials resulted in reductions in the air exchange rate to levels as low as 0.1 air changes per hour (ac/h). The effect on utility bills was equally dramatic, since space heating and cooling are two of the most costly uses of electricity and natural gas. As less heated or cooled air escaped the houses, less conditioning was required each hour.

However, one positive characteristic of the frequent air changes is that contaminants in the air are released from the house in a regular fashion. Airborne chemicals that can be dangerous to the inhabitants of a home (such as radon) are eliminated in a natural ventilation process. Without this ventilation, dangerous concentrations of radon can accumulate in energy-efficient, "tight" homes. This build-up normally goes unnoticed and unchecked, while the exposure of the inhabitants to this low-level radioactive agent is believed to produce harmful health effects.

Although direct data do not exist, EPA scientists estimated that, based on studies of uranium miners, from 5,000 to 20,000 lung cancer deaths a year in the United States may be attributed to radon (EPA 1984). More recently, a National Academy of Sciences study put the annual number at 13,000 deaths caused by radon exposure (Cohen 1988).

As a result of EPA's third year of state radon surveys released in 1989, the U.S. Surgeon General issued a national health advisory that recommended that most homes should be tested for accumulations of radon. Living in a home that registers 4.0 picocuries of radon per liter (pCi/L) poses an increased health risk if exposure is long-term, and the associated cancer risk for lifetime exposure is about a 50 percent increase in risk (EPA 1984).

Radioactivity in a gas is commonly measured in terms of the number of radioactive disintegrations per second per liter of air. One pCi/L is equivalent to 0.037 radioactive disintegrations per second per liter of air. Thus, 50 pCi/L would correspond to 1.85 disintegrations each second for every liter of air.

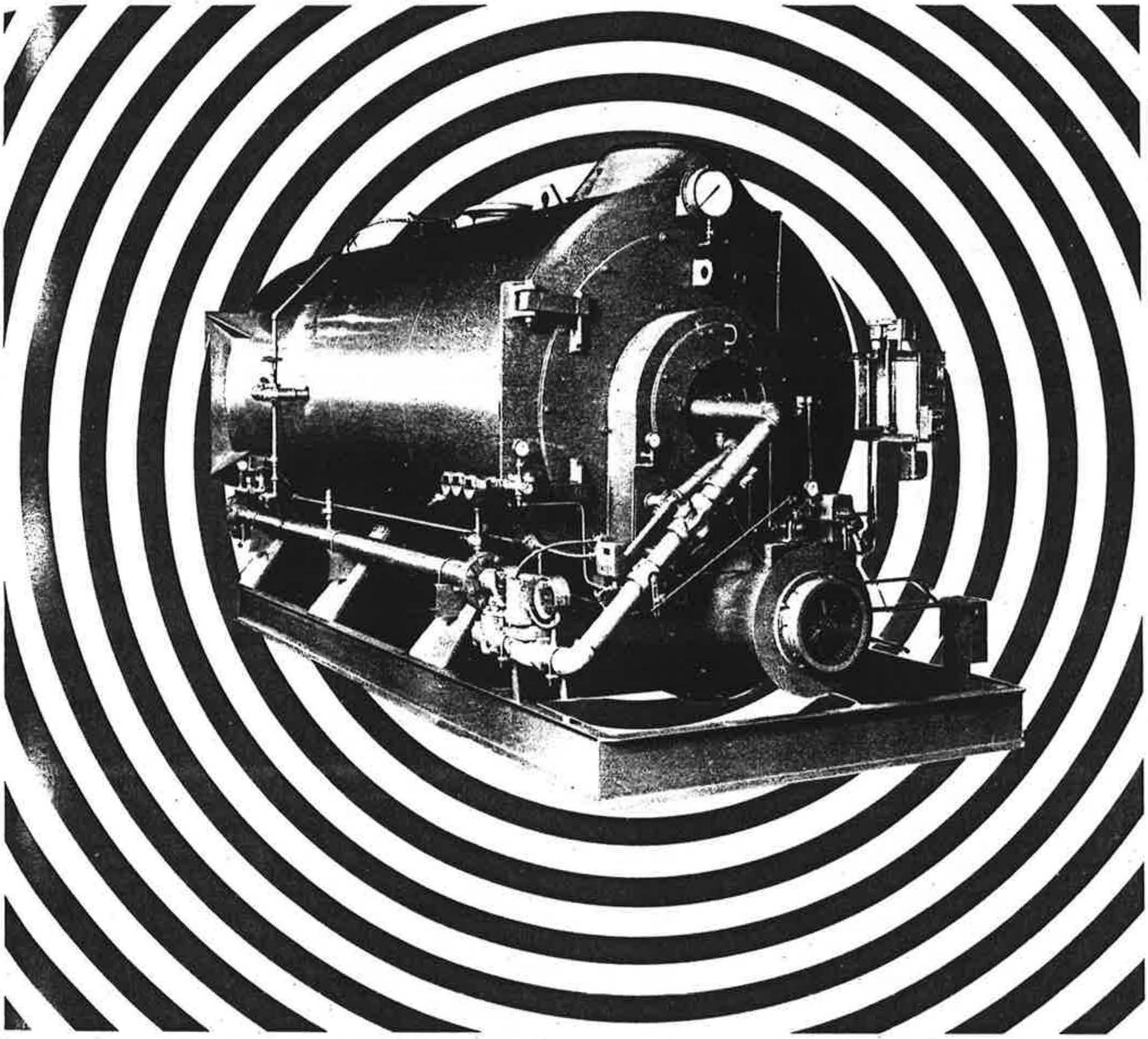
### The usual suspects

Among the housing characteristics that seem to be the most determinative of radon exposure are location, housing type, climate and air exchange rate. Of these, location appears to be the most important, but it is also the most difficult area in which to obtain accurate data. Location, in this instance, refers to houses built in the vicinity of known geological formations and types of soil that produce elevated levels of soil gas. These houses are more likely to experience exposure to indoor radon gas (Nero 1987). Tests have shown that these formations include (but are not limited to) deposits of uranium, shale, phosphate and granite where the uranium is decaying and produces radon gas.

Different housing types are more susceptible to radon infiltration than others. Houses with basements offer more opportunity for the gas to enter. Slab construction also can allow radon gas to infiltrate the home, although a properly sealed slab may provide more resistance because of the concrete mass between the earth and the living space. Crawlspace homes are the least susceptible if properly vented. Earth-sheltered and bermed houses (referred to herein as earthen homes) may allow more gases to enter, although improved vapor-barrier and ventilation techniques render these structures less permeable.

Air exchange rates may play an important role because homes with rapid air changes do not trap the radon gas for long periods of time, thereby reducing the risk of exposure. Thus, infiltration rates above a certain ac/h threshold, while not helpful to household energy budgets or national attempts at energy conservation, could provide a level of protection if radon infiltration is present.

Because national research has been inconclusive about both the absolute and relative importance of these factors, this study attempted to test the strength of these three factors as



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statistical predictors of high levels of radon in the home. Based on a sample of different housing types located either inside or outside of certain geological formations in Arkansas, the infiltration rates and radon levels were compared. In some locations, the results allowed homeowners and state health officials to determine where further radon testing needed to be pursued. This further testing is currently revealing higher than normal levels of radon gas in the three identified areas.

### The housing sample

What is problematic for health officials in the mid-South and other regions is that large-scale radon testing of each state's housing stock is relatively expensive and at odds with other public health priorities. Even EPA's program of state grants for radon testing requires some type of local matching funds. Funding for important public health programs such as infant immunizations and pre-natal care may suffer if radon testing at the level now recommended by the Surgeon General was implemented.

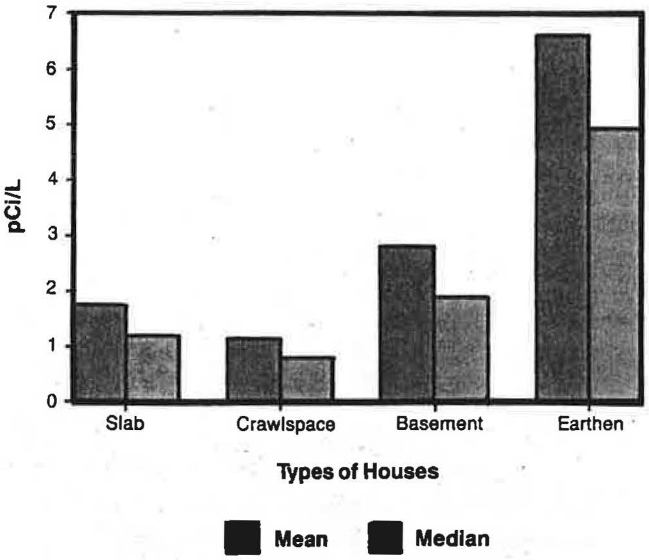


**Figure 1.** Average radon levels in Arkansas by housing type.

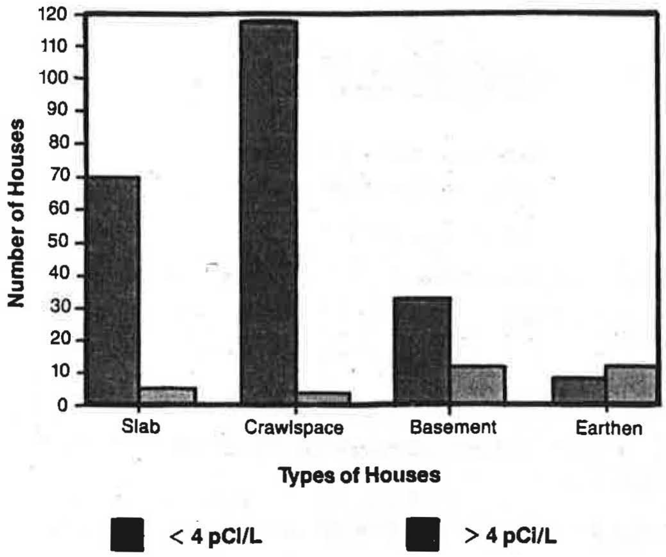


**Figure 2.** Radon above EPA levels in Arkansas homes.

The only feasible answer for many states is the testing of a sample of homes. This testing would focus on houses that are potentially at risk based on indicators detected in previous research (i.e., housing type and proximity to known geological formations) (Anon. 1987).

In Arkansas, to detect the location of acute radon exposure, a statistically valid sample of homes was inspected. A simple random sample of the state's homes was not sufficient for several important reasons:

- Based on known geology, potentially at-risk homes are concentrated in only two parts of the state;
- Only a portion of the total housing stock possesses the building characteristics that may generate dangerous levels of exposure; and
- Homeowners must cooperate with the inspectors if the comprehensive house examinations are conducted properly.

To accommodate these criteria, a sample of the state's homes was designed that allowed statistically valid conclusions to be drawn about the locations of serious exposure and the key variables that are known to affect radon levels: geological formations, housing types and levels of infiltration in a well-insulated (or "tight") home. The last parameter is used as an approximation for the air exchange rate in homes, and was measured by means of a "blower door" or pressurized home technique.

In the first phase of the research reported here, the state was divided into two groups: counties inside the geological zones defined as possibly at risk by EPA; and counties outside these zones. Inside the zones, several houses were selected in each area based on the proportionate size of the county and city populations. Outside the zone, at least one home was examined in most counties. In addition, a special category of earth-sheltered and bermed houses was analyzed. This approach is similar to the sampling technique used in the recent study of radon in California (Kai-Shen *et al.* 1990).

### Radon data analysis

Overall, 262 homes in Arkansas were tested for radon concentrations during 1989. The sub-group drawn from areas thought to have elevated levels of radon gas in the soil consisted of 199 homes. The remaining 63 residences were drawn from counties where the levels of radon within the soil gas are not believed to be high. Also included within the overall sample are results from measurements performed on about 20 underground or earthen houses.

Measurements were taken during January-March, 1989, using charcoal "pass-through" containers. The test kits were placed in the lowest lived-in area of the home for a period of three to five days. Taken in the aggregate, the mean concentration of radon in the 262 homes was 2.0 pCi/L, with a standard deviation of 3.3 pCi/L. Because of the sensitivity of these statistics to some extreme values reported for underground homes, the median concentration was lower at 1.1 pCi/L.

Similar results are observed when the data are analyzed according to geologic zone. As explained earlier, most of the observations were taken from those counties that were believed to have higher than normal concentrations of soil gas. For the 199 homes in those counties, the mean concentration was 2.1 pCi/L, with a standard deviation of 3.1. But, the mean was only slightly less (1.9 pCi/L) for the 63 residences not in these counties.

Overall, 12.6 percent (33 homes) had radon concentrations above the action level. Despite the absence of any apparent correlation between radon levels and geologic zone, it is

worth noting that only two homes outside of the zone had concentrations above 8.0 pCi/L.

Another variable that is worth studying for possible association with radon concentrations is the type of house being tested. For purposes of this investigation, four classes of homes were used that can be found throughout Arkansas in varying numbers. *Figure 1* shows average radon concentrations for each of the four classes of homes. The smallest mean concentration (1.1 pCi/L) occurs, as expected, among houses resting above crawlspaces, and the highest (6.6 pCi/L) occurs among underground homes. *Figure 1* also indicates that the means for crawl space, slab and basement homes fell well below the EPA action level.

*Figure 2* illustrates a different but equally remarkable result with respect to underground or earthen homes. Twelve (60 percent) of the 20 homes in this category tested at levels higher than 4.0 pCi/L, including one extremely high reading of 30.9 pCi/L. Only among basement homes did a comparable percentage (27 percent) of test results above the action level occur.

To determine whether in this case the data is statistically significant, a one-tailed binomial test was performed, using two different values—one high and one low—for the probability that radon concentrations in a home should exceed 4.0 pCi/L. Results from several recent studies done in the U.S. suggest that concentrations in seven percent of all single-family homes in this country exceed this EPA action level (Nero 1987). In this sample, the corresponding percentage was 12.6 percent. For the binomial test, both the Arkansas and the U.S. values were used.

Among homes with basement foundations, 12 of 45 (26.7 percent) exceeded 4.0 pCi/L. Among underground homes, 12 of 20 (60 percent) exceeded 4.0 pCi/L. The results of the test were statistically significant at the 0.01 level (i.e., for basement homes, $p = 0.0082$ and, for underground homes, $p = 0.0001$).

The sample of underground homes was small ($n = 20$), and it has been estimated that there are no more than 50 to 60 such structures in Arkansas. But the striking results suggest the likelihood of high radon concentrations is greater for underground or earthen-type structures. The number of potential entry points for radioactive soil gas is increased as more of the house is covered with earth.

The hypothesis that a drafty or well-ventilated house is not as likely to hold high concentrations of radon is complicated by the fact that some houses fitting this description may actually draw in more radon from beneath the house because of depressurization resulting from the ventilation of indoor air. Two variables that may potentially influence indoor radon levels are the age of the house and the number of air changes per hour occurring in the house. The former may relate only indirectly with radon concentrations in that, on average, older houses tend to be leakier and draftier than newer, tighter houses.

*Figure 3* shows that most of those homes with concentrations greater than 4.0 pCi/L were less than 25 years old, whereas only five homes that were over 25 years old exceeded the action level. Moreover, among the five homes in the latter group, none had radon concentrations above 6.0 pCi/L. Thus, the data suggests that the oldest homes were not as likely to have high radon levels, though it remains unclear whether this can be attributed to ventilation within the homes.

Unfortunately, it is difficult to assess the relation between air change rates and radon levels because blower-door test results were obtained for only 63 houses. Furthermore, only five of these had concentrations exceeding 4.0 pCi/L, far too few to support any definite conclusions about how air change rates may affect high radon levels. However, it is worth mentioning that none of the five homes with elevated concentrations reported an ac/h above 0.6. Alternatively, 32 homes had readings above 0.6 ac/h, and none of these exceeded the 4.0 pCi/L level.

Nero has estimated, on the basis of 22 separate studies of indoor radon levels, that "7 percent (or about 4 million) of the U.S. single-family housing stock have concentrations greater than 4.0 pCi/L" (Nero 1987). His analysis of these studies also yields an aggregate mean of 1.5 pCi/L for the nation's housing stock. At this time, the available data for Arkansas do not imply any significant departure from the national picture.

Further statistical tests using multivariate regression techniques were performed on the data. Although only a small number of the homes with infiltration tests registered high levels of radon, the regression results showed some tentative patterns. Summarizing the variables of interest, the larger the air volume in the building and the busier the activity in the home reasonably correlate in a negative fashion with higher radon levels ($p = 0.0001$ and $p = 0.0792$, respectively).

The disturbing fact about the air-change variable is that tighter, more energy-efficient homes seem to correlate with higher levels of measured radon ($p = 0.0036$). Although the equations still leave much unexplained variation in the reported laboratory tests on the charcoal canisters used in the homes ($R^2 = 0.30$), at this point the model indicates that generally less efficient, "leaky" houses have an advantage of slightly reduced levels of radon.

Except for basement and underground homes, the evidence from this research, so far, appears encouraging. That evidence seems to show that few homes in Arkansas have significant concentrations of radon. Only further testing of basement and underground homes will confirm whether they contain higher concentrations than other types of houses.

### Summary and conclusions

Overall, the study of Arkansas homes points out that only certain groups of housing can be reasonably sure that radon exposure is not a problem. Quoting from Nero, "This suggests the need to recognize that the broad distributions...do not of themselves reveal the much higher distributions that may occur in specific areas" (Nero 1987). Individual homes appear in this and other studies in locations that contradict the dominant local pattern by registering high levels of radon.

In view of the potential danger of radon exposure and the

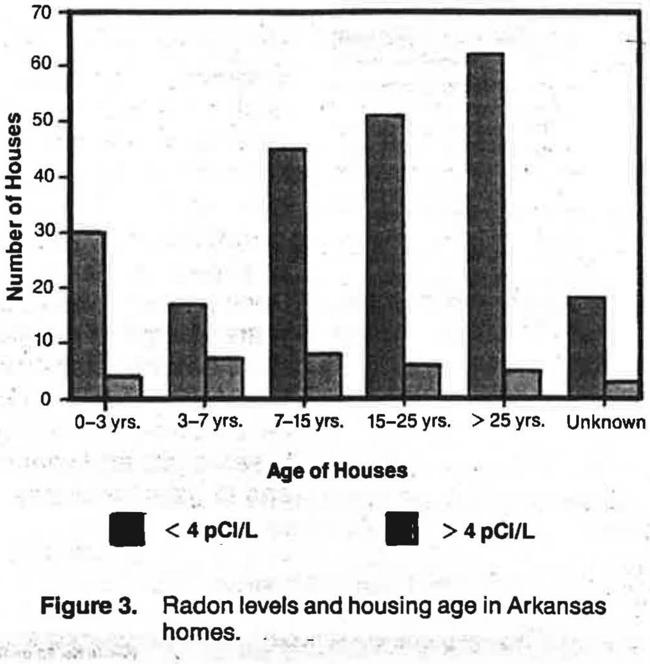


**Figure 3.** Radon levels and housing age in Arkansas homes.

public's interest in avoiding exposure to high radon levels, the following conclusions arise from this study.

Geographic or geologic patterns alone do not normally explain the presence of high levels of radon gas in individual homes in Arkansas. Although high level homes were found within such geologic areas in western and northwestern parts of the state, high levels of radon (in several cases above 8 pCi/L) also were found away from the suspected formations in central Arkansas.

The data support one simple rule. Older houses (i.e., 25 years or older) do not appear to trap radon and therefore do not contain higher levels of the gas. The tests on 62 homes older than 25 years reveal only five instances of radon above the action level.

Use of a blower-door test can provide another definitive rule. Homes with a natural air-change rate greater than one per hour do not appear to trap the radon either. The 63 radon tests on houses where an independent blower-door test showed more than 0.6 ac/h revealed only five instances of radon above the action level.

In Arkansas, it is clear that earth-bermed, earth-sheltered and, to a lesser extent, basement houses have a higher probability of radon exposure above the action levels. This conclusion is supported by the finding of a statistically significant relationship between such houses and radon levels above 4.0 pCi/L. The conclusion is made stronger by the fact that the housing sample contained almost 40 percent of the known earth-bermed and earth-sheltered houses in the state. ■

**Acknowledgments**

The author wishes to thank Eric Melvin, who assisted in compiling and analyzing the housing data used in this article. Data collection was supervised by Phillip Patterson of Energy Rated Homes, Little Rock, Arkansas. The cooperation of the Arkansas Department of Health sanitarians in identifying prospective homes for testing is gratefully acknowledged.

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