

Radon in the Gulf Coast Area: Potential Problem or Exaggerated Risk?

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Abstract

Indoor air pollution from radon has been identified by the U.S. Environmental Protection Agency (U.S. EPA) as a serious health problem; estimates indicate that radon is the second-leading cause of lung cancer (after smoking) and that high levels of radon may cause as many as 20,000 to 40,000 lung cancer deaths per year in the United States. Studies of the potential risk in the Gulf Coast have been few. This report summarizes more than 7,000 previously unreported radon analyses and relates them to geological information in order to identify possible problem areas for the Gulf Coast region of Louisiana, Texas, Mississippi, Alabama, and Florida.

High levels of indoor radon are generally associated with older "crystalline" igneous and metamorphic bedrock. Thus, most areas of the Gulf Coast are relatively low risk because they are underlain by Cenozoic sedimentary rocks and unconsolidated deposits. However, some types of sedimentary deposits, such as "black shale" and phosphate-rich rocks, can be areas of high risk. According to the U.S. EPA indoor radon survey results the percentage of houses with screening levels greater than 4 pCi/l (picocuries per liter) for given states is as follows: AL = 6.0%; LA = 0.8%; MS = 2.0%; and TX = 4.0% (no data available for FL). The data developed in the current study indicate that the percentage of houses with greater than 4 pCi/l for given states is as follows: AL = 6.1%; LA = 0.6%; MS = 2.0%; TX = 1.6%; and FL = 4.5%. The areas that appear to have the greatest risk are parts of northern Alabama and Mississippi, central Texas, and some areas in Florida.

Introduction

Significant health problems have been attributed to high levels of radon in indoor air in many areas of the United States and elsewhere (e.g., Fisher, 1989; Nero, 1989; Raloff, 1990; Gundersen, 1991a, 1992). Although some sources have recently questioned the seriousness and detrimental health effects of elevated radon levels (e.g., Neuberger et al., 1992; Cole, 1994), other widespread government and consumer publications estimate that radon is a leading cause of lung cancer (Consumer Reports, 1990; U.S. Environmental Protection Agency, 1991) and that high levels of radon may cause many thousands of deaths each year in this country (Hurlbut, 1989). Consumer Reports (1990, p. 31) claims that "Radon poses a greater health risk than any other environmental pollutant" and "... inhaled radon causes between 10,000 and 40,000 lung-cancer deaths each year."

Public perception and awareness of the radon problem is relatively low, and published reports analyzing the associated risk are relatively few. This report summarizes more than 7,000 previously unreported radon analyses from Alabama, Florida, Louisiana, Mississippi, and Texas. In addition, this paper attempts to relate areas of potentially high radon occurrences to possible geologic parameters so that the problem will be better understood by the scientific community, who will then be able to communicate this issue to the public.

Nature of the Problem

Origin of Indoor Radon

Radon is a naturally occurring radioactive gas that is part of the U and Th decay series (Fig. 1). The most common isotope is ^{222}Rn , hereafter referred to simply as radon, and it occurs in the $^{238}\text{U} - ^{206}\text{Pb}$ decay chain. The immediate parent of radon is ^{226}Ra , but it is radon's daughter products (Fig. 1) that cause the main health problems (Nazaroff and Nero, 1988). Radon ultimately originates from radioactive elements in rocks and soils. Specific problem areas are typically found where bedrock is composed of igneous and/or metamorphic rocks. Other less common "hot spots" are found in areas with unusual sedimentary rocks, such as black shale and phosphate-rich rock, as well as areas associated with anomalous manmade concentrations of radioactive materials, commonly called Naturally Occurring Radioactive Material (NORM) or Technologically Enhanced Natural Radioactive Environment (TENRE).

Radon is an inert gas, and, therefore, once it is created by radioactive decay of uranium in earth materials, it can move relatively freely in the subsurface. It moves primarily by diffusion and convection caused by concentration and pressure gradients, although temperature differences can also be important. The normal flow of air in and out of a house will also carry radon from the ground. Major path-

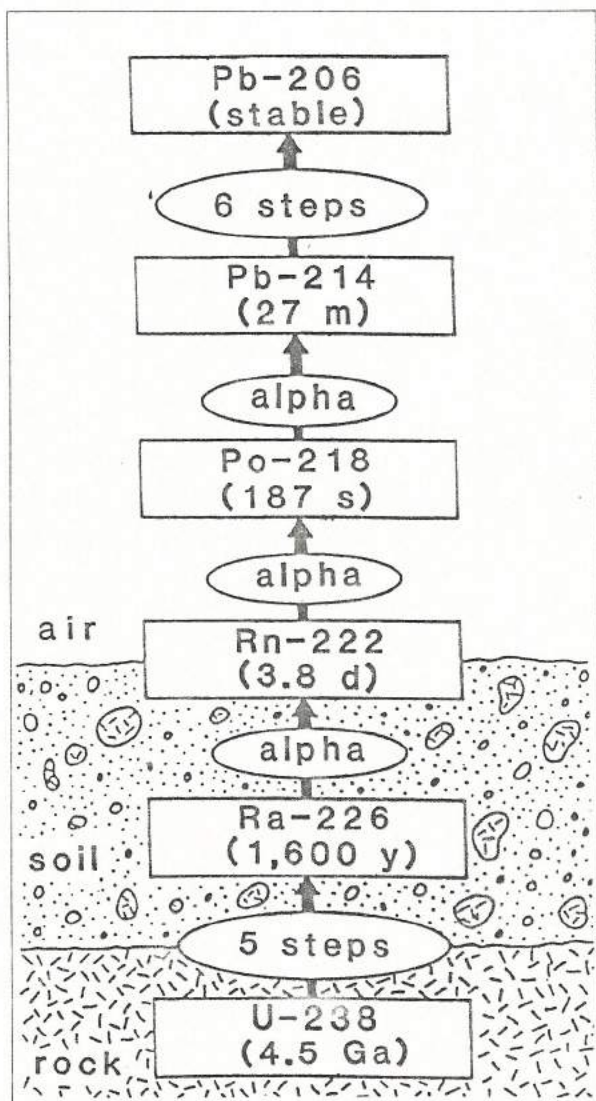


Figure 1. Simplified radioactive decay scheme from uranium-238 to lead-206. Half-lives are shown in parentheses. Type of decay is listed for some isotopes, but not all isotopes are shown (from Hodges, 1988).

ways for radon entry into buildings are summarized in Figure 2 and include cracks, joints, pores, and loose fittings around pipes or walls; exposed soil or bedrock; building materials; and drainage pipes. In addition, radon can be released into household air if the water supply contains high radon levels. Generally, surface- and municipal-water supplies have very low levels of radon, whereas untreated ground water can be a significant source of radon.

Newer houses and those that are sealed more tightly for energy efficiency tend to hold radon more effectively than older or poorly insulated residences, although any type of house can have high radon levels. Once radon enters the house it can become trapped or concentrated in a variety of places. Basements, crawlspaces, sump pumps, or other low-lying spaces in a building can serve to concentrate radon because radon is heavier than air.

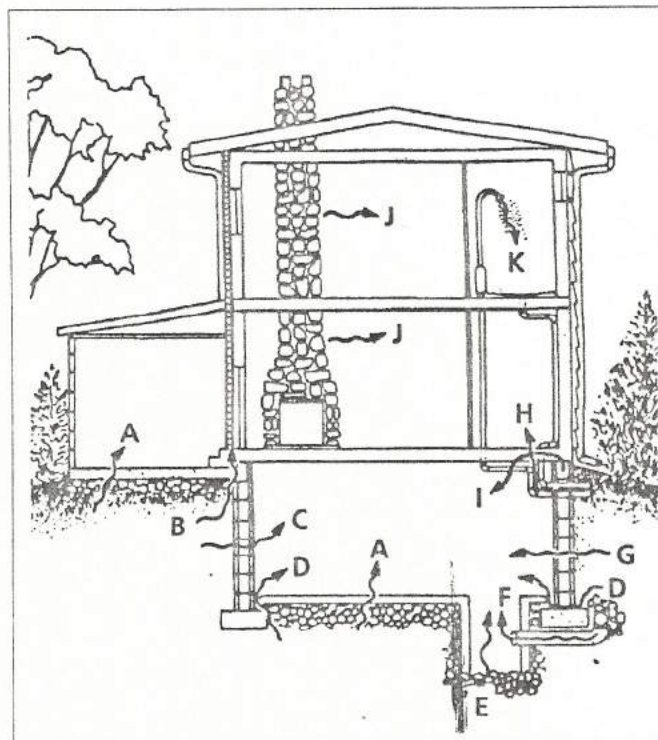


Figure 2. Possible radon entry routes to buildings: A - cracks in concrete slabs; B - hollow spaces behind walls; C - pores and cracks in concrete blocks; D - floor-wall joints; E - exposed soil; F - weeping drain tile; G - mortar joints; H - loose-fitting pipes; I - open tops of block walls; J - building materials; K - well water (from U.S. EPA, 1993b).

Radon by itself can cause damage if it undergoes radioactive decay when it is inhaled into the lungs. More commonly, adverse effects result from daughter products of radon, which are solid nongaseous elements, most notably polonium and lead (Fig. 1). When radon decays in the air, these daughter products tend to "plate out" on materials such as dust. When dust is inhaled it can lodge in the lung cavity, and subsequent decay of the radioactive daughter products of radon can result in damage to delicate lung tissue.

Risk Associated with Radon

Many articles have debated the health risks associated with high levels of indoor radon. The summary presented here is not intended as a total review of the literature but is meant as a brief clarification of the significant viewpoints. Any time the relative health risk of any parameter is evaluated there will be a wide spectrum of opinions. This is certainly true with respect to radon. Most studies agree that extremely high levels of radon as found, for example, in underground mines, especially those producing uranium ore, can be related to increased incidence of lung cancer (e.g., Barretto, 1975; National Council on Radiation Protection and Measurements, 1984; National Academy of Sciences, 1988; Cole, 1994; Page, 1994). Many of the same studies

pCi/l	number of deaths*	Comparable exposure levels	Comparable risk
200	440 - 770	1000 times average outdoor level	more than 60 times non-smoker risk
100	270 - 630	100 times average indoor level	4 pack-a-day smoker
40	120 - 380		20,000 chest x-rays/yr
			2 pack-a-day smoker
20	60 - 210	100 times average outdoor level	1 pack-a-day smoker
10	30 - 120	10 times average indoor level	5 times non-smoker risk
4	13 - 50		200 chest x-rays/yr
2	7 - 30	10 times average outdoor level	non smoker risk of dying from lung cancer
1	3 - 13	Average indoor level	20 chest x-rays/yr
0.2	1 - 3	Average outdoor level	

* estimated number of lung cancer deaths due to radon exposure (out of 1000)

Figure 3. Estimated risk associated with radon compared to other activities (from U.S. EPA, 1986).

state that major points of contention arise in interpreting risk associated with low-level, long-term exposure to radon and in determining what level should be set for remedial action (see also Cole, 1993).

This study will use the limits and standards that have been established by the U.S. EPA, which has published data to inform the public of the severity of the problem and degree of risk (U.S. EPA, 1986). A chart showing the estimated risk associated with various levels of radon is reproduced in Figure 3.

The results of radon analyses are typically listed by the U.S. EPA as the percentage of houses with levels greater than that at which action is recommended—that is, 4 pCi/l. Figure 4 shows the cumulative 40-state indoor radon survey results. In addition, the U.S. EPA lists data on a state-by-state basis that show the average and highest level of radon as well as the precise percentage of houses with levels greater than 4 pCi/l. The latter quantity is sometimes referred to as the "failure rate" for a given area. Recently the U.S. EPA published a map of the United States that

identifies, on a county-by-county basis, the potential for elevated levels of indoor radon. The portion of that map that deals with the Gulf Coast region is presented in Figure 5.

Results and Discussion

Results of radon analyses for the Gulf Coast area are summarized in Table 1 and compared to similar data for the cumulative 40-state U.S. EPA indoor radon survey results. Generally, the results from both studies are similar, although some minor differences exist. It should be pointed out that the results presented in the current study are summarized from a national radon testing company, which does most of its work with relocation companies during real estate transactions. Radon levels were measured with activated charcoal canisters and electric ion "e-perm" detectors. Most of the tests are conducted in major metropolitan areas, in large industrialized regions, or near government complexes. Thus the results presented here do not necessarily represent a thorough coverage of the study area. Also, there is an unequal coverage from state to state. Nevertheless, the data given here include a large number of analyses that can point out significant problem areas and trends. Data are discussed first on a state-by-state basis and then for the area as a whole.

Alabama

The results from Alabama are remarkably similar to the U.S. EPA data. Out of 663 tests, 42 were greater than 4 pCi/l, which yields a failure rate of 6.3%. This compares favorably to the 6% rate listed in the U.S. EPA study. Almost 98% of the tests that failed in this study are from the northeastern part of the state in the general vicinity of Birmingham, Anniston, and Huntsville. The high results are within the area that was shown by Gundersen (1992) to have higher radon potential (Fig. 5). Bedrock in that part of the state is older rocks associated with the Appalachian Mountains.

Louisiana

Out of 352 cases reported in Louisiana, 2 were above the limit of 4 pCi/l. The failure rate for this study is 0.6%, which is quite similar to the U.S. EPA rate of 0.8%. This is the lowest failure rate for this study and one of the lowest in the nation. Obviously, these data are very limited and should be evaluated with caution. However, the fact that some houses have been found with high levels of radon shows that, indeed, the risk is real and similar results could be seen in other parts of the state. For example, ground water in the central part of the state has been found to have anomalously high concentrations of radioactive uranium and radium (U.S. Geological Survey, 1988). Because these elements are the precursors of radon, this part of the state appears to have the greatest potential for having elevated levels of radon. In general, however, the problem of indoor radon does not appear as widespread in Louisiana as in other states.

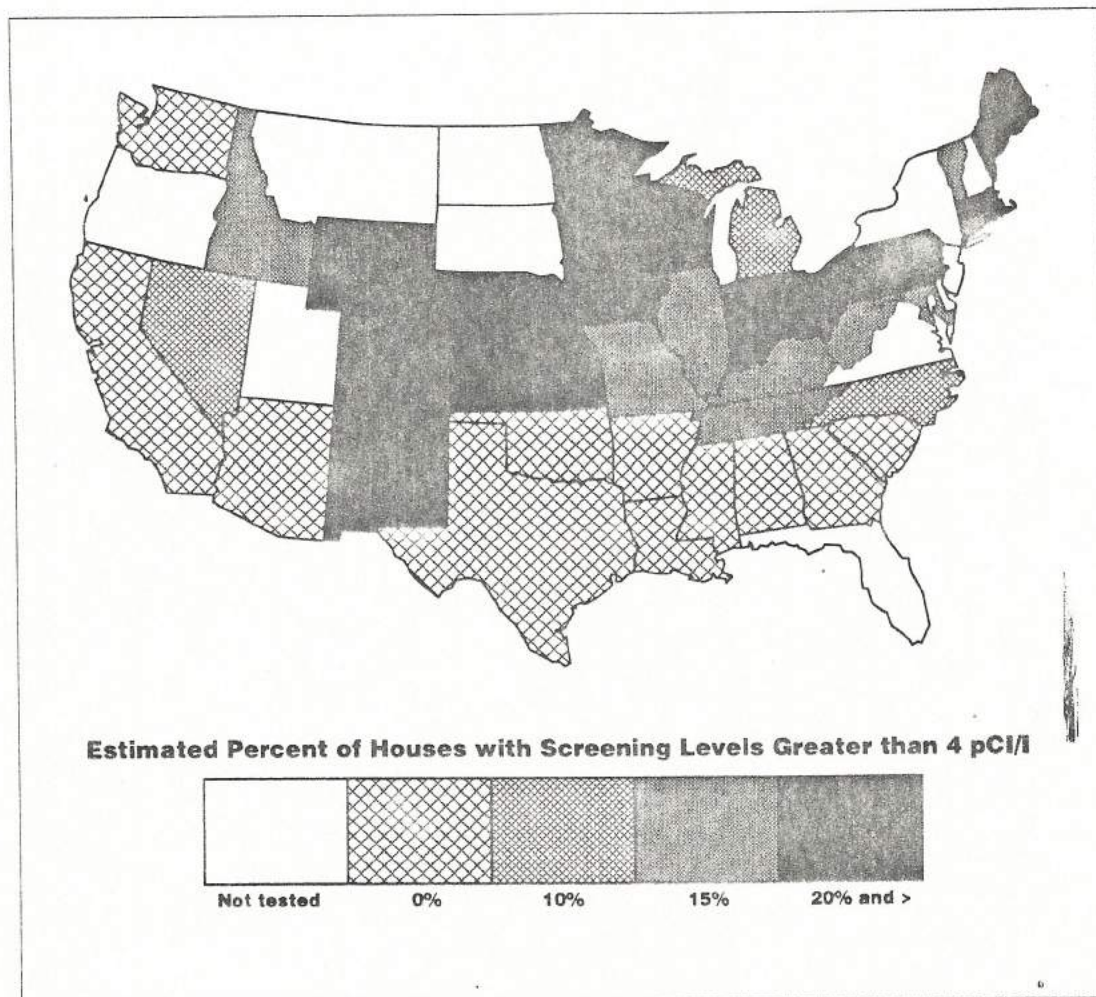


Figure 4. Cumulative 40-state EPA Indoor Radon Survey results showing estimated percent of houses with screening levels greater than 4 pCi/l (from U.S. EPA, 1993a).

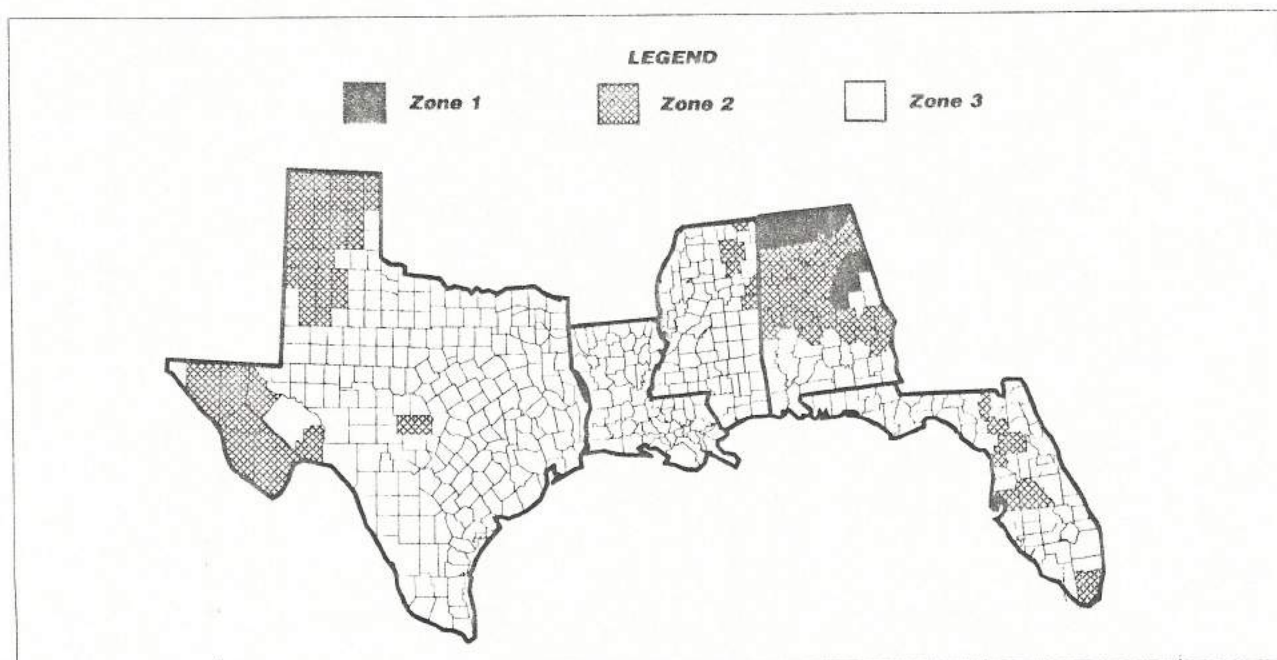


Figure 5. Map of radon zones for the U.S. on a county-by-county basis. Zones have predicted average indoor screening levels as follows: 1 - greater than 4 pCi/l; 2 - between 2 and 4 pCi/l; 3 - less than 2 pCi/l (from U.S. EPA, 1993a).

Table 1. Results of radon analyses as reported by the EPA (1993a) and in this study. Average and highest levels are given in pCi/l (picocuries per liter). Results are discussed in the text.

	EPA Results			This Study	
	Average Level	Highest Level	% > 4 pCi/l	Highest Level	% > 4 pCi/l
AL	1.8	180	6	16.7	6.1
FL	*	*	*	36.4	4.5
LA	0.5	8	0.8	5.8	0.6
MS	0.9	23	2	7.3	2.0
TX	1.7	66	4	15.6	1.6

*no data available

Florida

As of the time of writing, the U.S. EPA had not summarized the statewide radon data for Florida (Table 1), although they have the data for individual counties (Fig. 5). The data for Florida are much more abundant and are a bit more difficult to interpret. A total of 3,526 analyses produced 160 with a level above 4 pCi/l, for a failure rate of 4.5%. Virtually all parts of the state have recorded values above the recommended limit. However, the largest proportion of the high levels are found in two general vicinities, around the Miami area and in central Florida, between and near the cities of Tampa, Lakeland, Orlando, and Gainesville. These are areas formerly identified as having potentially high levels of indoor radon (Gundersen, 1992).

The Miami-Homestead area accounts for about 22% of the high results in Florida. The area is underlain primarily by limestone, which can be a source of radon if it has a high uranium concentration, and limestone-derived soils, in which uranium can be enriched because the easily soluble carbonate matter has been removed. The central Florida region in large part also sits on limestone, which can be a source of radon as above, but in addition the area has some phosphate-rich sedimentary rocks, which in many cases have high concentrations of uranium and hence can also be a source of radon. The central part of the state accounts for more than half of the high radon levels and contains the highest result found in this study (Table 1). The northern part of Florida and the panhandle are the areas that have the fewest number of high-radon occurrences.

Mississippi

Mississippi has the fewest number of tests for any state in this study, although the failure rate is above that of Louisiana. A total of 5 tests out of 244 were above the recommended action level, which is a failure rate of 2.0%. As with the sparse Louisiana data, these results should be interpreted with caution because the area is not thoroughly covered. There may be areas where high radon levels could be a problem, as reported, for example, in the northeast part of the state (Gundersen, 1992). A second example that

involves a high radon level is associated with a NORM site. A private test conducted in central Mississippi at a house built on an abandoned pipe-cleaning facility yielded a result of 15.2 pCi/l for a short-term test. Furthermore, the five sites with high radon levels do not fit into either of these categories, and, therefore, similar levels could be found in other parts of the state.

Texas

The results for Texas are quite variable. The failure rate of about 1.6% was derived from 44 results greater than 4 pCi/l out of 2,648 analyses. Although radon and other radioactive elements have been found in ground water in various parts of Texas, including the Gulf Coast area (Cech et al., 1988; Wise, 1990) and the panhandle (Bartolino, 1991), this does not appear to be a serious problem as far as indoor radon is concerned. Data presented in other studies (Gundersen, 1992; Fig. 5, this paper) indicate that parts of Central Texas, Trans-Pecos Texas, and the Panhandle are potential problem areas for high radon levels.

The data from this study only partly agree with previous work. High radon levels are found in the Panhandle, where 32% of the high analyses occur, and in the north-central part of the state near Dallas, where 41% of the elevated levels occur. However, no high levels of radon occur in Trans-Pecos Texas, although nearly a hundred tests have been conducted in El Paso, nor in the Llano Uplift area of Central Texas, which consists predominantly of Precambrian igneous and metamorphic rocks. The areal distribution of tests in the Trans-Pecos region is probably not adequate to estimate the probability of high radon levels. Only a very few tests have been done in the Llano Uplift area, and the number of samples is inadequate to show radon levels.

Summary

The results of this study show that high radon levels in indoor air can be correlated with the general rock type in a particular area, although there are some exceptions and omissions. High radon levels are found, for example, in the following circumstances: areas underlain by older igneous,

sedimentary, and metamorphic rocks like the Precambrian, Paleozoic, and Cretaceous rocks in northern Alabama; areas of limestone and their derived soils, such as in the Tertiary to Quaternary deposits of central and southern Florida and the Cretaceous rocks in North-Central Texas; areas associated with phosphate-rich rocks as in central Florida; and areas of unusual sedimentary rocks, like those found in the Pliocene sediments of the Texas Panhandle.

Two regions that were previously identified as having high radon potential but are not identified as such in this study are Trans-Pecos Texas and the Llano Uplift of Central Texas. These zones were not detected in this study because analyses reported here are commonly associated with large population centers and not with relatively sparsely populated regions. The lack of detection of high levels of radon or the presence of radon in low levels in a particular area in this study does not imply that there is no risk. Indeed, as the U.S. EPA (1993a) stresses in their county-by-county map of radon zones for the entire nation (summarized in Fig. 5, this study), homes with elevated levels of radon have been found in all of their zones. Elevated levels of radon could be found essentially anywhere and, therefore, the U.S. EPA recommends that all homes be tested for radon.

High levels of radon have been found in many parts of this study area, even those associated with the zones of lowest radon occurrence. These high levels could be attributed to a variety of features not necessarily related to the bedrock beneath a particular site. For example, high levels of radon have been found in association with fault zones (King et al., 1991), shear zones (Gundersen, 1991b; Stanton et al., 1991), fracture systems (LeGrand, 1987; Banwell and Parizek, 1988), and active earthquakes (Igarashi and Wakita, 1990; Kodai and Takahashi, 1992). It is possible that faults and fractures in Cenozoic or older deposits could be a source of high radon levels. Although no such situation has been positively identified, the occurrence of numerous high radon levels in the Dallas area could be related to the Balcones Fault Zone.

It is also possible that radon could originate from hydrocarbon deposits and/or the results of their production. Radon has been found in anomalously high concentrations in natural gas and deep sediments in the Gulf Coast (Kraemer, 1986, 1991). With the large number of natural gas occurrences that have been found in this region, it is possible that high radon levels could be associated with hydrocarbon wells, processing facilities, or seeps. Additionally, radon is known to be associated with NORM deposits that form as a direct result of oil or gas production. A final possibility, suggested by Gundersen (1991a), is that radon could be associated with heavy mineral deposits containing uranium-bearing minerals.

Conclusions

The results of this study indicate that large parts of the Gulf Coast Association of Geological Societies area have a low potential for elevated levels of indoor radon. This has been noted for some parts of the area and for other Gulf Coast states (Gundersen and Peake, 1992) and is most likely because this area is primarily underlain by Cenozoic sediments and sedimentary rocks that have low abundances of

radioactive materials, especially those that are the parents of radon. Areas that have higher concentrations of elevated radon levels can be correlated with older Precambrian, Paleozoic, or Mesozoic bedrock or associated with unusual rock types. High levels of radon have been found throughout the study area and cannot be attributed directly to any of these sources. These occurrences may be caused by fault, shear, or fracture zones; hydrocarbon production and its byproducts; heavy mineral concentrations; or other as yet unidentified processes.

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