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Indoor radon and its sources in the ground

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Introduction

Radon is a radioactive element that is produced by the radioactive decay of radium, which itself is derived indirectly from uranium. When radon disintegrates, it produces radioactive decay products that are now recognized as an important cause of lung cancer. Uranium, radium, and radon are naturally present in very small concentrations in nearly all soils and rocks. There are typically only a few radon atoms among the 10,000,000,000,000,000 molecules of air in a pore space in the soil. The radon atoms do not combine with other elements but can diffuse or can be carried along with air from the soil into a house through openings such as cracks, joints, sumps, and utility penetrations in basement foundations and walls or through floor openings from crawl spaces above the soil.

What causes soil air to move into a house?

Soil air moves into a house when the air pressure inside the house is lower--even if only a hundredth of a percent lower-- than the atmospheric (barometric) pressure outdoors. Wind blowing by the house can reduce the air pressure in the house, depending upon the positions of open windows and other openings. If the air in the house is warmer than the outdoor air, it is more buoyant, can leak out at the upper levels of the house, and "draw" cooler air in from below, just as a fireplace does. In effect, lowered air pressure makes the house a large vacuum cleaner, sucking some air from the soil and some air from the outdoors near ground level.

If an ice or clay layer, asphalt apron, or concrete deck outside offers resistance to the movement of air from the soil to the atmosphere, and the pathway through the house offers less resistance, then falling barometric pressure can cause soil air to move into the house. Heavy rainfall also can increase the movement of soil air into the house.

What determines how much radon can get into the house?

First, there has to be radium in the soil. Some radium is almost always present in soil, but its concentration ranges over about a factor of ten. Other things being equal, soils with higher concentrations of radium are potentially more hazardous.

Second, the radon, which is constantly being created by disintegration of radium, has to be able to get into the soil pores and move fairly quickly into the house. Ninety percent of a given amount of radon will decay in 13 days enroute. If the soil "breathes" easily, the radon can move; conversely, if the soil does not "breathe", the radon decays before it can move more than a foot or so.

Third, there must be porous building material or openings below ground level to permit radon or radon-bearing soil air to move into the house. If a house is well sealed below ground level, much of the radon decays before it can pass through most building materials.

Fourth, it is likely that reduced air pressure indoors, which forces air to flow into the house, is needed to produce a serious indoor radon problem. Some radon may enter without movement of air by a process known as diffusion, but it is thought to be less important for entry of radon into a building than air flow driven by pressure difference.

Are there maps showing radon distribution in the soil?

Direct measurements of radon in soil are not often made. However, radiations from one of the radon decay products can be measured from aircraft and provide an approximate measurement of the radon in the top foot of an area of the ground below. Such measurements were made in strips covering much of the area of the 48 States and some of Alaska as part of the National Uranium Resource Evaluation (NURE) program. Complex processing of the measurements is required to make accurate maps, and only the radiometric maps of Ohio are currently available. Because the flight strips of the NURE program left gaps in the coverage, the information is not satisfactory for detail in areas smaller than about six miles in diameter. No matter how accurate and detailed a radon map may be, it represents only one of the four major factors that determine whether an indoor radon hazard exists in a house. At present, we expect that some localities having potential for excessive indoor radon exposure exist in all the States.

What controls radon movement in the ground?

Radium in rock and soil contributes radon to the soil air only if the radium is very close to the surfaces of the rock and soil grains. In many rocks, only a few percent of the radium disintegrations produce radon that can get into the pore spaces. In most soils, a fifth to half of the radon can get into pore spaces. In extremely dry soil, however, most radon stays in the solid material.

Once radon is in the rock or soil pores, the amount of water in the ground is very important. If the pores are filled with water, radon can move only a few inches before it decays; if only a small amount of water is present, radon may move a hundred times farther. The distance the radon can move tends to be greater in fractured rocks and coarse soils and gravels, and much less in fine-grained soils like silt and clay, which also tend to hold water. Air and water carry radon by flow much more easily through coarse and fractured material than through fine-grained soil.

What types of ground favor indoor radon problems?

Remember that it takes a combination of factors to cause an indoor radon problem: (1) radium in the ground, (2) ease of radon movement in the ground, (3) porous building materials or openings below grade, and generally (4) lowered atmospheric pressure in the building. Few of the measurements of indoor radon made to date have been carefully related to the soil and underlying rock types on which the houses are sited.

The criteria given below are based on scientific principles, rather than on proven correlations between certain rock and soil types and radon concentrations in houses built on them.

Rock types to suspect: Granites, many gneisses, phosphatic rocks, and dark marine shales typically contain higher than normal levels of radium; if these rocks are fractured, they can be important sources of radon. When limestones and dolomites recrystallize, they exclude uranium and radium from the new crystals and concentrate them in the pores and along surfaces that fracture easily, so that radon can be picked up and carried by air or water moving along the fractures. Sandstone is not usually enriched in radium, but it is the host rock for uranium deposits in some areas of the West. Well water derived from the above rock types may contain such high concentrations of radon that a significant amount of radon is liberated from the water in showers and other domestic uses, in addition to radon entering from the soil.

Soils to suspect: Some residual soils, particularly those known as terra rossas (reddish-brown soils sometimes found over limestone bedrock), have become enriched in radium as other parts of the soil have been leached away. Coarse, well-drained soils allow radon-bearing air to move easily and may make radon available to a building even if the soil itself does not contain much radium. Gravels and coarse sands are possible trouble-makers. At the other extreme, clays and muds, particularly if they are usually wet and extend to the lowest foundation level, should not permit much radon movement into a building even if their radium concentration is greater than normal. Ground that does not pass the percolation test (of the suitability of the ground for a septic drain field) should not pass dangerous amounts of radon.

Topographic effects: Houses built on hillsides and ridges are apt to be located on soils that are coarser and better drained than soils in adjacent valleys. They are also apt to be closer to bedrock which, if fractured, may yield more radon than the soil.

What can be done to prevent radon entry into buildings?

The U. S. Environmental Protection Agency advises that measures currently being investigated in State or federal projects include:

Sealing foundation cracks and openings around basement drains and utility pipes or cables with caulking compounds or epoxy sealants.

Ventilating crawl spaces or underfloor areas such as sumps or other drain systems.

Ventilating the inner hollow spaces of concrete blocks in basement walls.

Covering earth inside or under the building by using concrete or a tightly sealed polymeric vapor barrier.

Ventilating the area around entrances to the basement (such as where pipes come in or cracks in the wall or floor) and then exhausting this air to the outdoors.

Controlling the building ventilation rate through the use of air-to-air heat exchangers.

How can the radon level be tested?

Radon measurements require special instruments or detectors. Radiation protection bureaus of some States, some local health departments, and some utility companies have facilities or arrangements for making indoor radon measurements. The references cite some sources of detectors. The U. S. Environmental Protection Agency has established a "hot line", 1-800-334-8571, extension 7131, from which general information can be obtained; effective in late May 1986, lists will be available of detector vendors participating in a voluntary quality control program.

References for further reading:

"Indoor Air Pollution", in Consumer Reports, October, 1985, includes information about indoor radon and one type of detector that can be obtained.

"Radon Exclusive", in Popular Science, November, 1985, features a lengthy article on indoor radon and cites two sources of radon detectors for homeowner use.

"The Radon Report", in Rodale's New Shelter magazine, January, 1986, is a feature article. Contrary to statements in the article, slab-on-grade houses are less likely to collect radon than houses with basements. The article's map should be used with great caution, because it is based on regional occurrences of bedrock that tend to contain greater-than-average radium concentration, which is only one of the factors that create indoor radon problems. Parts of the shaded areas should not have been shaded because the bedrock is not exposed near the surface. Many localities not shaded on the map may have high potential for indoor radon exposure because of local enrichment of rock or soil by radium or because of particularly low resistance of the rock or soil to movement of radon-bearing air.

"The Indoor Radon Story", in Technology Review, January, 1986, was written by Anthony V. Nero, Jr., leader of the extensive program of indoor radon investigations conducted by the Lawrence Berkeley Laboratory, and is the most authoritative of the popular publications so far.

Indoor Air and Human Health, edited by R. B. Gammage and S. V. Kaye and published by Lewis Publishers, Inc., 121 S. Main Street, P. O. Drawer 519, Chelsea, MI 48118 (ISBN 0-87371-006-1), is a 1985 book that contains technical articles on radon sources, radon dosimetric and risk models, epidemiology of radon decay products as a cause of lung cancer, and European radon surveys and risk assessment.

Guidance and information about remedial action may become available from the U. S. Environmental Protection Agency, Radon Program, 401 M Street, S. W., Washington, DC 20460.