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Radium in Ground Water from Public-Water Supplies in Northern Illinois

Concentrations of the naturally occurring radioactive isotopes radium-226 and radium-228 in excess of the U.S. Environmental Protection Agency standard for drinking water of 5 picocuries per liter have been detected in water from deep aquifers used for public supply that underly parts of northern Illinois (fig. 1). Radium, a known carcinogen, has the potential to cause bone and sinus cancer if ingested in sufficient amounts. This Fact Sheet briefly describes the formation and decay of radium, the health risks associated with radium ingestion, procedures for testing radium concentrations in water, and the occurrence of radium in ground water used for public-water supplies in northern Illinois and provides information on technologies that can reduce the amount of radium in drinking water.

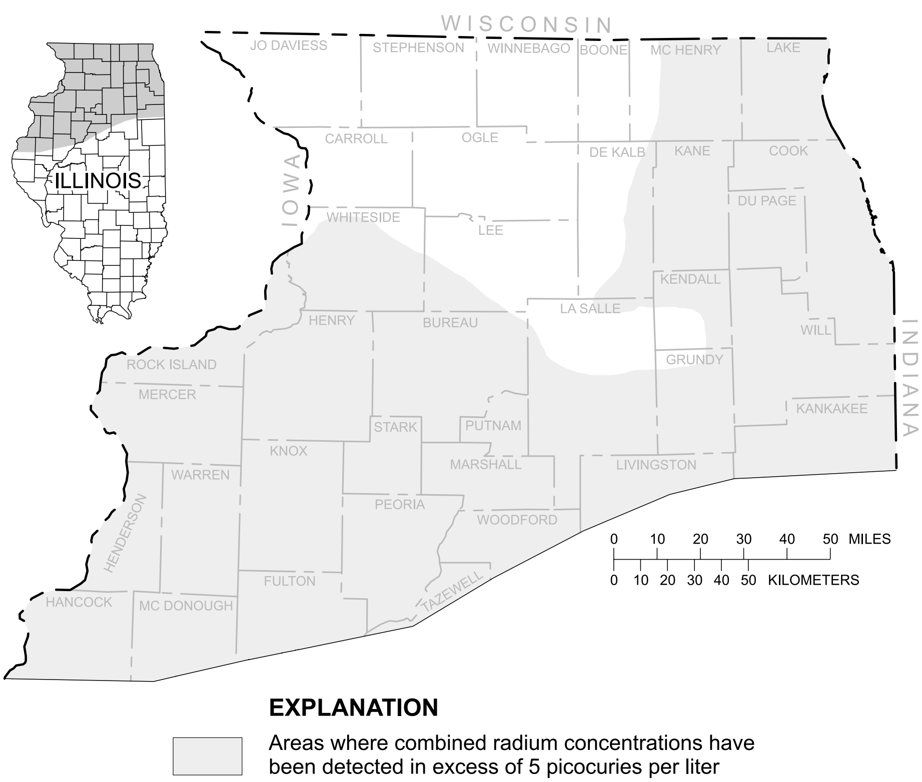

Figure 1. Areas where radium concentrations in excess of 5 picocuries per liter have been detected in aquifers used for public-water supply in northern Illinois.

What is radium and why is it present in ground water?

Naturally occurring unstable radioactive elements are found in all rocks, soil, and water. The common long-lived radioactive elements, uranium and thorium, decay slowly to produce other radioactive elements, such as radium, which also undergo radioactive decay. The rate of radioactive decay is constant and is expressed as a half-life, the time required for one-half of the initial number of atoms of a specific radioactive element to decay.

The two most common isotopes of radium in water are radium-226 (the most common) and radium-228. Radium-226 is a disintegration product of uranium-238 and is formed when the nucleus of a helium atom (an alpha particle) is emitted from the nucleus of the decaying thorium-230 nuclide (figs. 2 and 3). Radium-226 has a half-life of about 1,600 years. Radium-226 decays by the emission of an alpha particle to radon-222. Thorium-232 decays directly to radium-228 by the emission of an alpha particle. Radium-228 has a half-life of 5.75 years. Radium-228 decays by the emission of an electron (beta particle) to actinium-228.

Radium-226 and radium-228 are moderately soluble in water. Radium can enter ground water by dissolution of aquifer materials, desorption from rock or sediment surfaces, and ejection from minerals by radioactive decay. Naturally occurring radium has been detected at elevated concentrations in ground water from two deep aquifers underlying northern Illinois used for public supply, the Mt. Simon and Cambrian-Ordovician

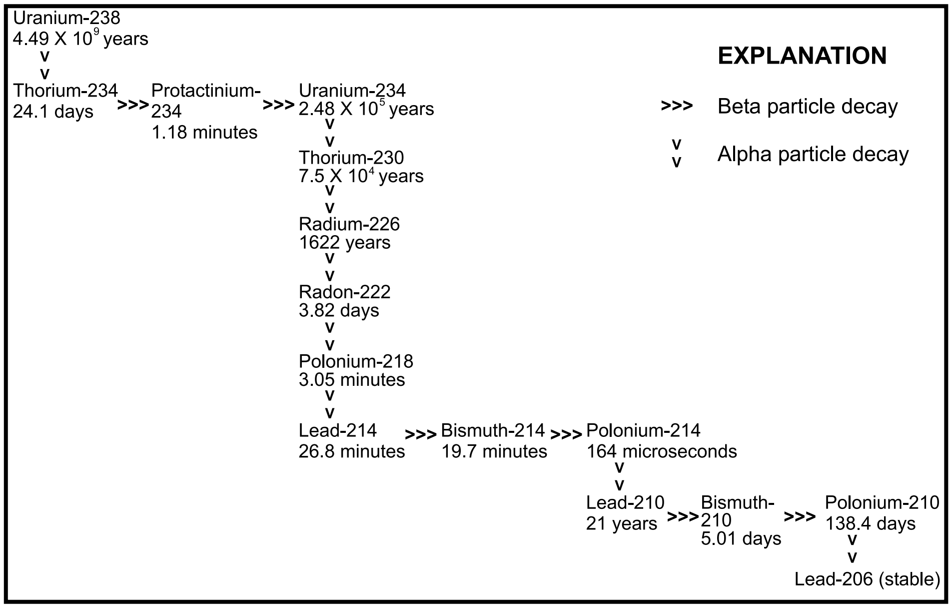

Figure 2. Radioactive decay series and half-lives of uranium-238 through lead-206.

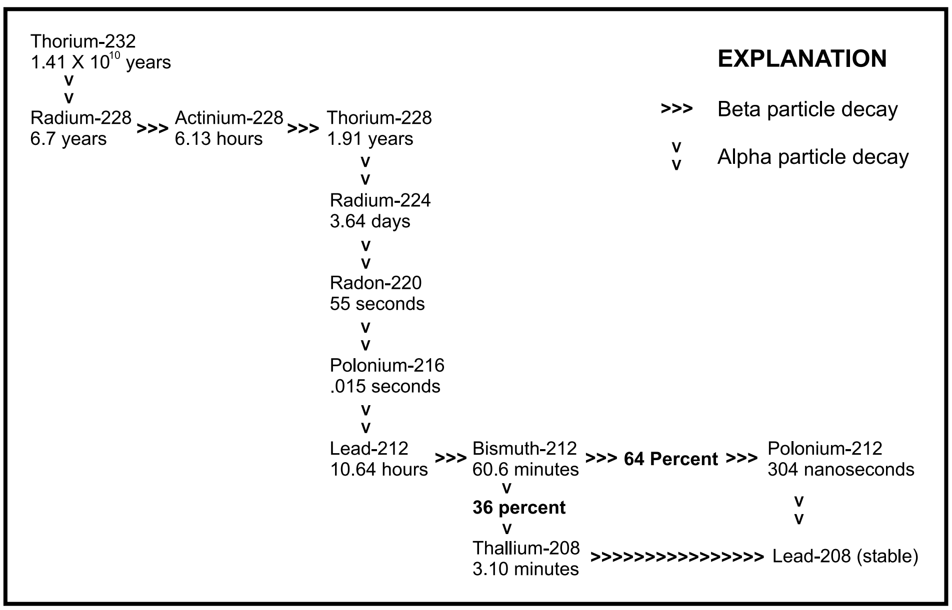

Figure 3. Radioactive decays series and half-lives of thorium-232 through lead-208.

(Lucas and Ilcewicz, 1958, Gilkeson and others, 1984, Lucas, 1985).

Why is radium in drinking water of concern?

The human body metabolizes radium in much the same way that it metabolizes calcium. Because of this similar metabolism, ingestion of trace quantities of radium over time will result in an accumulation of radium in the skeleton. Radium that has accumulated in bone tissue decays into a series of short-lived daughter products, resulting in the emission of a number of alpha and beta particles over a short time span (figs. 2 and 3). As radium and its daughter elements decay, the energy produced by the radiation can strip electrons from the atoms with which it collides. These stripped electrons have a great capacity to break chemical bonds as they travel through living tissue, causing the release of additional electrons. The atoms in living tissue that lose electrons become ions at a high energy state capable of producing chemical reactions that would not have been otherwise possible, resulting in damage to bones and other living tissue as well as to genetic material inside the tissue cells. Ultimately, the damage from continuous exposure to radium can potentially cause bone and sinus cancer (Mays and others, 1985).

What level of radium in drinking water constitutes a health risk?

The U.S. Environmental Protection Agency (USEPA) has estimated that the additional lifetime risk of cancer associated with drinking water that emits alpha-particle radiation at 15 picocuries per liter (pCi/L)[1] of water, or has a combined concentration of radium-226 and radium-228 of 5 pCi/L of water, is about 1 in 10,000. The risk doubles to 2 in 10,000 at 10 pCi/L and triples to 3 in 10,000 at 15 pCi/L. This analysis means that if 10,000 people were to consume 2 liters of water containing 5 pCi/L of radium every day for 70 years, one additional fatal cancer would be expected in the 10,000 people exposed. Consequently, USEPA regulations set the drinking water standard at an average annual concentration of gross alpha-particle radioactivity in drinking water to 15 pCi/L and the average annual combined concentration of radium-226 and radium-228 to 5 pCi/L.

The increased cancer risk from long-term ingestion of radium should be viewed in the context of current cancer statistics. Analysis of cancer statistics presented by the American Cancer Society on the World Wide Web at *http://www2.cancer.org/cid/509.00/index.htm* indicates that approximately 4,400 in 10,000 Americans will develop cancer at some point in their lifetimes, and approximately 2,200 of the 10,000 eventually will die of cancer. Drinking water containing radioactivity at the maximum level permitted under the Safe Drinking Water Act (5 pCi/L for

[1]Picocuries per liter is a measure of the activity of a radioactive compound in water with 1 pCi/L being equal to 2.2 radioactive disintegrations per minute per liter of water.

radium-226 and radium-228 combined) will increase by one the number of deaths in the 10,000 people so exposed.

How are public-water supplies monitored for radium?

All new sources of water for public supply in the United States must be monitored for radioactivity on a quarterly basis for a full year. The testing process for radium begins with an analysis of gross alpha-particle activity, which is a measure of the total amount of alpha radiation given off by the water. Because radium-226 emits an alpha particle during decay, gross alpha-particle activity is used as a screening tool to indicate the presence of radium-226 in a water sample. If the average gross alpha-particle activity of the quarterly samples exceeds 5 pCi/L, testing for radium-226 and radium-228 is required. If the average gross-alpha particle activity in all samples is greater than 15 pCi/L, or if the combined concentration of radium-226 and radium-228 exceeds 5 pCi/L, the water system is monitored quarterly for an extended period. After the initial year of testing, water supplies with lower concentrations of gross-alpha particle activity or radium are monitored on a less frequent basis. Operators of water-supply systems that exceed the radium or gross alpha standard are required to notify consumers on a quarterly basis.

What is the extent of elevated radium in water from aquifers used for public-water supply in Illinois?

With a few exceptions, radium concentrations in ground water from aquifers used for public-water supply in Illinois exceed the USEPA standard only in the Mt. Simon and Cambrian-Ordovician aquifers in northern Illinois. The area of concern where elevated radium concentrations were detected in the Mt. Simon and Cambrian-Ordovician aquifers extends from Kankakee, Livingston, Woodford, Tazewell, Fulton, McDonough, and Hancock Counties north to the Illinois-Wisconsin State line (fig. 1). Because the depth of these aquifers is typically greater than 500 feet below land surface, these aquifers typically are used for water supply by municipalities, not by individual homeowners. Additional information on radium in ground water from the Mt. Simon and Cambrian-Ordovician aquifers in northern Illinois can be obtained from the World Wide Web at *http://il.water.usgs.gov/proj/gwstudies/radium*.

How can I reduce the amount of radium in my drinking water?

Commonly, water delivered to homeowners from public-supply systems has been treated to reduce the concentration of radium below the USEPA standard. Water-treatment processes such as ion-exchange softening, lime softening, and filtration to remove iron can appreciably reduce gross alpha radiation and radium-226 concentrations in ground water and are being used by a number of municipalities in Illinois to reduce the radium concentration in water delivered to homeowners. Some municipalities dilute water that contains elevated concentrations of radium by blending it with surface water or water from aquifers containing lower concentrations of radium. Several municipalities in northeastern Illinois have stopped using ground water altogether (for reasons other than the amount of radium in the water) and now use water from Lake Michigan as their sole water supply.

Water softeners, ion exchange, or reverse osmosis water-treatment systems also can be installed in the home to reduce radium concentrations. Homeowners using water softeners, ion exchange, or reverse osmosis systems should maintain them according to the manufacturer's directions. For help in selecting the size and type of treatment device, homeowners should consider contacting the Water Quality Association at the following address and telephone number:

Water Quality Association
International Headquarters
and Laboratory
4151 Naperville Road
Lisle, IL 60532-1088
1-800-749-0234

or they can be reached on the World Wide Web at *www.wqa.org*

For help in determining the effectiveness of a particular home treatment system in reducing radioactivity in their water, homeowners may contact the National Sanitation Foundation (NSF). The NSF develops voluntary standards for various products and provides testing and certification against those standards. The NSF may be reached at the following address and telephone number:

National Sanitation Foundation
International
3475 Plymouth Road
Ann Arbor, MI 48113-0140
1-800-673-8010

or they can be reached on the World Wide Web at *www.nsf.org*

Persons who install a water-treatment system may consider analyzing their water for radium or gross alpha radioactivity after installation to verify that the system is working effectively to reduce radioactivity to an acceptable level. Persons who are concerned about radium concentrations in water from their private wells also may consider having their water analyzed. To find a laboratory capable of testing for radium or other radioactive compounds, contact the Illinois Department of Nuclear Safety at 217-786-6399 for a list of approved laboratories.

—*Robert T. Kay*

SUGGESTIONS FOR FURTHER READING

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For additional information contact:

Robert Kay
U.S. Geological Survey
1420 Sycamore Road
DeKalb, IL 60115
(815) 756-9207
e-mail RTKAY@USGS.GOV

U.S. Geological Survey, WRD
221 North Broadway Avenue
Urbana, IL 61801