What is radium? Is it in drinking water?

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Radium (Ra) is a naturally occurring radioactive element present in varying amounts in rocks and soil within the earth's crust. Under natural conditions, radium leaches into groundwater from radium bearing rocks. All rocks contain some radium in small amounts. Radium readily dissolves in groundwater when the pH levels of water are low. In general, surface water is low in radium; however, deep bedrock aquifers used for drinking water sometimes contain radium above regulatory standards.

Groundwater, which flows through pores in underground layers of rock, dissolves minerals as it flows. If the rock contains significant amounts of radium, and the groundwater moves at a slow enough rate, the water picks up higher amounts of radium.

Most low-level aquifers do not contain significant amounts of radium. However, radium has been found in some private and public wells. Radium cannot be seen, tasted, or smelled in drinking water. Unless the water supply is tested for radium, the presence or absence of radium cannot be confirmed. Immediate health risks from drinking water containing low radioactivity levels are small, but consuming this water for a lifetime increases the health risks.

The list of man-made radium sources includes stormwater runoff from mining operations, discharges from industrial and medical activities, and fallout from nuclear weapons detonation or accidental discharge from nuclear power facilities.

Radium, like any other chemical, can be present in several isotopes that have different radioactive properties, and the most common isotopes in groundwater are Ra 226 and Ra 228. Isotopes are atoms with the same number of protons but a different number of neutrons. An atom of radium has 88 protons and the two well-known radium isotopes contain 138 and 140 neutrons, respectively. Since the atomic mass number of a chemical is the sum of protons and neutrons, isotopes of radium are represented as Ra 226 (88+138) and Ra 228 (88+140).

What is radioactivity?

Radioactive substances undergo spontaneous nuclear decay, thereby emitting various forms of radiation energy. The primary form of radiation emitted by radium is the alpha particle. Most naturally occurring radioactive elements emit alpha particles during their decay process. Presence of alpha particles in water indicates the presence of a radioactive substance. Other radioactive substances, besides radium, may contribute to radioactivity in water.

Water testing for radium should be started with a test for gross alpha particle activity, the measure of the total amount of radioactivity of water. If gross alpha activity is observed, further testing for radium should be carried out. Radioactivity levels of water are measured in "picocuries" per liter (pCi/l).

Is radium regulated?

The U.S. Environmental Protection Agency (EPA) has established maximum contaminant levels (MCLs) for combined radium 226 and 228 and for gross alpha radiation in drinking water. The MCL for combined radium 226 and 228 is 5 pCi/l. The MCL for gross alpha is 15 pCi/l. Standards have not been established yet for Ra 224 or other alpha emitters.

The MCL set for radium is well below levels at which health effects have been observed, and, hence, is assumed to protect public health. The EPA has proposed to raise the standard for radium in drinking water to 20 pCi/l based on a reevaluation of potential health risks from radium and other radioactive elements.

What are the health effects of radium?

Naturally occurring levels of radiation in drinking water are not considered to pose a health emergency. The estimated health risks from low levels of radium are small and short-term exposures pose extremely small levels of risk. The risk associated with consuming water containing 5 pCi/l of radium for one year is comparable to one chest X-ray. There are no health risks associated with bathing, washing dishes, or doing laundry with water containing radium since the skin blocks the alpha radiation.

Radium is known to cause bone cancer if consumed in high doses. A National Academy of Sciences report states that long-term exposure to higher levels of radium in drinking water causes a higher risk of bone cancer. Studies of workers who ingested high levels of radium from occupational activities show that radium causes bone cancer. According to the EPA, long-term consumption of water containing 5 pCi/l radium may cause 44 additional cancer deaths for every million people exposed. The risk increases as the level of radium increases.

Radium, like other elements, naturally enters the body through water and food consumption.

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No more than 20 percent of the ingested radium is absorbed from the digestive tract and distributed throughout the body. Internally deposited radium emits radiation as alpha particles that may then damage surrounding tissues. Radium is chemically and structurally similar to calcium, and the body absorbs it into bones. When swallowed, a small amount of radium attaches to bones, but most leaves the body in feces or urine.

However, studies of workers exposed to high levels of radium and other sources of alpha radiation for extended periods, show that these high levels may cause anemia, cataracts, fractured teeth, and even affect the immune system, in addition to causing some types of cancer.

How can a radium problem be countered?

Quality, operation and maintenance of equipment, dependability, and economy are the important factors to consider when dealing with unacceptable levels of radium. The list of solutions includes, a new water source, blending water from more than one source, or removing radium by treatment. The first two are preferable options since they are less expensive and avoid waste disposal problems. A source of treated surface water or groundwater with lower radium content, drawn from a different source, can replace or be mixed with an existing source.

Systems unable to employ these non-treatment measures must choose the treatment option. One fairly inexpensive treatment method is ion exchange, which is used in home water softeners. This process removes approximately 90 percent of radium.

The ion exchange process for radium removal is similar to the process for hardness removal. In this process, sodium (or hydrogen) ions are exchanged for radium. Once the ion exchange resins are exhausted, the resins need to be regenerated with common salt or a dilute acid. The exchange capacity of the resin and the amount of regeneration liquid required are the factors to be considered in the ion exchange process. The regenerant solution and resin wash-water contain dissolved contaminants that require disposal in a safe manner. In some cases, however, the ion exchange process can cause the undesired effect of adding sodium to the treated water, a factor those on low sodium diets also should consider before installing a softener.

Another possible treatment method is lime-soda ash softening. Laboratory studies have demonstrated an average 80 percent removal. In this process, lime and soda are added to water and combine chemically with radium to convert it into insoluble compound. This insoluble compound precipitates as a sludge, which can be removed from water by gravity settling and disposed of in a safe manner.

Reverse osmosis (RO) can remove about 90 percent of radium. With RO, the contaminated water is forced through a semi-permeable membrane that will not allow dissolved substances to pass through. Radium is removed from water by passing it through the membrane. Pumping pressure is an important design consideration of this process. The reject solution from this process contains high levels of dissolved solids and needs special disposal considerations.

When selecting the treatment process, concentrations of radium in raw and finished water should be considered.

Does treatment create secondary waste?

As discussed earlier, all treatment processes produce wastewater and solid waste (sludge) containing radium in varied concentrations. These treatment byproducts must be disposed of properly and safely. The list of disposal methods includes, sanitary landfill, discharge into surface waters, underground injection, application on farmlands for soil neutralization or reuse for road stabilization. As the wastes from the treatment processes vary in radium concentrations, the disposal method should be selected appropriately. Pertinent laws and regulations must be understood and followed before disposing of these wastes. (For more information, see *Tech Brief: Water Treatment Plant Residuals Management*, item #DWBLPE65. See back page to order.)

How is radium treated in private wells?

Of the treatment methods described earlier, ion exchange using zeolite softening is effective for home use. Radium, however, can get past an improperly maintained softener. Users need to monitor softeners periodically to assure they are operating properly.

Small "RO" units and distillation units may be effective in radium removal in home systems, but the units have limited capacity and severely restrict water flow. The devices can only be used to treat water from a single faucet rather than the entire water supply. Additionally, other water quality problems, such as high iron or manganese, may interfere with these treatment methods.

References

1. *Radionuclide Removal for Small Public Water Systems*. 1983. U.S. Environmental Protection Agency.
2. Kannapell, A. 1998. "Drinking water and what else? From Wells in South Jersey Flow Radium, and Anxiety." *New York Times*. *http://junkscience.com/news3/radium.htm*
3. *Radium in Drinking Water*. 1999. Fact Sheet by Illinois Department of Public Health. *http://www.idph.state.il.us/envhealth/factsheets/radium.htm*
4. *Frequently Asked Questions about Radium in Drinking Water*. 1999. Wisconsin Department of Natural Resources. *http://www,dnr.state.wi.us/org/water/dwg/radium.htm*
5. Subramanian, S., Clifford, D. and Vijjeswarapu, W. 1990. "Evaluating Ion Exchange for Removing Radium from Groundwater," *Journal AWWA*.
6. Clifford, D. and Zhang, Z. 1994. "Modifying Ion Exchange for Combined Removal of Uranium and Radium," *Journal AWWA*.
7. "Radionuclides: Small System Regulatory Requirements under the Safe Drinking Water Act as amended in 1996." *http://www.epa.gov/ogwdw000/smallsys/ndwac/radionuc.html*