Illinois State Water Survey

WATER RESOURCES BUILDING • MAIL: BOX 232, URBANA, ILLINOIS 61801 • AREA CODE 217
605 E. SPRINGFIELD. CHAMPAIGN PHONE 333-2210

WILLIAM C. ACKERMANN, CHIEF

Subject: Technical Letter 19 February 1977
Removal of Water Supply Contaminants -- Radium

This is the fifth in a series of Technical Letters dealing with state of the art methods for removal of contaminants from water supplies so that the supply will be in compliance with the federal and state drinking water standards.

Contaminants

This Technical Letter is concerned with the radioactive element radium (Ra) as a contaminant of drinking water. At the present time there are over 300 wells in Illinois which have gross alpha activities above 3 picocuries per liter (pc/l). The activities range from about 63 to 3 pc/l. The gross alpha count is not a specific measure of radium but indicates that the level of naturally occurring Ra-226 may be high. Most of the supplies with high gross alpha levels are located in a band which spreads southwest and northwest from Cook County. Many of the supplies are deep wells into sandstone. There are also a large number of scattered sites throughout the state.

Prevalence and Uses

Radium is a naturally occurring radioactive element found in nature. Radium has no non-radioactive isotopes. It is one of the products of the radioactive decay of uranium (U). The longest lived isotope is Ra-226 which is formed in the natural decay of U-238. The other major radium isotope is Ra-228. It is produced from the decay of radioactive thorium, and has a much shorter half-life than Ra-226.

Radium is found in groundwater supplies due to leaching from geological deposits or due to contamination from uranium ore process waste or disposal of radioactive waste. In Illinois the radium is from natural sources.

Radium has been used for radiotherapy and for coating of watch hands and numerals for luminous dials. Its uses have primarily been supplanted by other less expensive man-made radioactive isotopes.

Health Effects

Concern over radium is due to its radioactivity. Radium is similar to calcium in its chemistry so it becomes deposited in the bone where it remains for a long period of time. Continual ingestion of small amounts of radium results in the accumulation of radium in the body. The accumulated radium can give rise to localized radiation damage to surrounding tissue. Particularly susceptible is the blood and blood forming tissue in the bone marrow. This results in anemia as well as destruction of the bones.

Maximum Levels

The maximum levels of radium are based on the measured radioactivity. If the gross alpha activity exceeds 5 pc/1 the supply must be monitored specifically for Ra-226. If the Ra-226 level exceeds 3 pc/1 the supply must be analyzed for Ra-228.

Remova1

Radium behaves chemical1y very similarly to calcium. Techniques used for calcium removal should be effective in removing radium from drinking water.

A. Ion Exchange

Radium can effectively be removed from drinking water by ion exchange softening. The radium is exchanged along with the calcium and magnesium hardness. In the ion exchange softening process the elements removed from the water are replaced by sodium. The ions which are removed are washed from the resin using a brine solution. Regeneration of the resin by means of a brine wash is required when the resin becomes saturated with the elements being removed, since it is no longer effective. For effective radium removal the resin must be regenerated as soon as calcium breakthrough occurs.

Since ion exchange softening removes all the hardness, it is necessary to blend the finished water or to treat the finished water to prevent corrosion of the distribution system. Blending of finished water with raw water will result in decreased cost of removal. The ratio of raw to finished water which can be used will be dependent on the level of radium in the raw water.

B. Lime Softening

Lime softening is reported to be as effective as ion exchange for the removal of radium. The radium is precipitated and carried down with the calcium during softening. Since complete softening of the water does not occur, no blending would be required. However, depending oh the level of radium in the raw water, blending may be used to reduce the amount of water which is treated.

The lime softening process does not require as close monitoring as the ion exchange since no regeneration is required. There may be some limitations on the process for high levels of radium and low hardness; however, this is an unlikely situation for any water supply in Illinois.

C. Reverse Osmosis

Reverse osmosis involves the removal of soluble minerals by passage of water through a semipermeable membrane. To get water to pass through the membrane it is necessary to apply pressure to the water containing the minerals to overcome the natural direction of flow which would be for pure water to diffuse into the mineral-containing water. The amount of pressure necessary is dependent on the mineral content of the raw water. Although reverse osmosis can be used to reduce the radium level, its application is impractical and costly unless it is already in use for the treatment of brackish water. The most significant cost is plant construction. For a 1000 m^3/day plant (183 gpm), cost will be about $250,000 based on 1976 costs. This cost does not include costs for any interest during construction, site and site improvement, discharge facilities, storage and delivery facilities, or special treatment. Operating costs are about $18,000 for a plant of that capacity.

D. Electrodialysis

Electrodialysis involves the removal of salts by means of ion selective membranes and a d.c. current to assist transport of the ions across the membrane. There is depletion of ions on one side of the membrane if current is passed for any length of time, while there is concentration on the other side of the membrane. Any level of desalting can be achieved by increasing the residence time or increasing the current density.

For efficient operation good water pretreatment is required. This should include coagulation of colloidal particles, oxidation of iron and soluble organics, carbon filtration, and finally acidification.

Although this process can be used for the reduction of radium levels, its application is impractical and costly even if other contaminants are to be removed unless the equipment is already in use or planned for use to reduce brackish water to an acceptable salt level. The cost for electrodialysis is dependent on the level of contaminant to be reduced. In general it will be more costly than reverse osmosis. The pH of the effluent may require adjustment to protect the distribution system.

E. Distillation

Distillation involves the volatilization of water to separate it from all dissolved or suspended materials which are not volatilized. Normally the water is heated under pressure to improve the thermal efficiency of the method by recovering some of the heat. This process produces water of very low dissolved solids. Since the water is corrosive to the distribution system, it is necessary to increase the salt content. This can normally be accomplished by appropriate blending of the finished water and the raw water.

Some pretreatment of the feed-water may be necessary. Most often only deaeration is necessary, but in some situations it may be necessary to remove suspended solids and calcium and magnesium to prevent scaling.

Distillation is a relatively expensive and impractical solution for the removal of specific contaminants from water. The process involves the removal of a large volume of water from a small amount of dissolved material. This results in an unfavorable energy requirement since it is essentially independent of the contaminant level and only dependent on the amount of water to be treated. The major cost is plant construction which will be about $1.2 million for a 1000 m^3/day plant (183 gpm) . The operating costs for energy are also high, since there is only partial heat recovery in this process.

General Comments

It should be noted that a primary concern with any process is waste disposal. Waste rinse water or sludge will be radioactive so conventional disposal techniques can not be used. Because of the uncertainty about the waste disposal problem no cost figures can be given because it is quite likely that waste disposal costs will be a significant part of the total costs. It appears at the present time that disposal of the waste at a hazardous waste disposal site will be acceptable.

All of the removal techniques discussed above require pilot-scale testing for a specific application to determine their efficiency. Pilot-scale studies are also needed to determine what, if any, pretreatment is necessary to insure good operating efficiency. All of the processes which effectively demineralize the water require some adjustment of pH and/or hardness and alkalinity to prevent corrosion of the distribution system.

Technical Letters are issued as part of the Water Survey's continuing service to citizens of Illinois. Should you need further clarification, please let us know.

Very truly yours,

Dr. Francis Amore

Dr. Francis Amore
Associate Professional Scientist

[2-77-6000]