Radionuclides in Drinking Water

Radionuclides are radioactive isotopes that can occur naturally or result from manmade sources. Natural radiation comes from cosmic rays, naturally-occurring radioactive elements in the earth's crust, and radioactive decay products. Since these radionuclides are present in soil and rock, they can also be found in groundwater and surface water. Typical radionuclides found in drinking water sources are isotopes of radium, uranium, and radon, among others. Fission products from manmade nuclear reactions are also of concern today, particularly radioactive cesium and iodine.

The three basic types of radiation are alpha particles, beta particles, and gamma rays. Alpha particles are positively charged helium atoms; beta particles are negatively charged electrons, and gamma rays are high-energy electromagnetic waves.

Radiation exposure can occur by ingesting, inhaling, injecting, or absorbing radioactive materials. The amount of radiation exposure is usually expressed in a unit called millirem (mR or mrem), which is a measure of energy deposited in human tissue and its ability to produce biological damage. According to the U.S. Environmental Protection Agency (EPA), the average annual radiation dose per person in the U.S. is 620 mrem. Drinking water measurements of radioactivity are typically expressed in picocuries per liter (pCi/L). The relationship between pCi to mrem is complex, because it depends on the type of isotope, its biological half-life, and the material absorbing the radiation.

Half-life is the time required for any given radioisotope to decay to one-half of its original quantity, and is a commonly reported measure of the speed with which that isotope undergoes radioactive decay. The half-life is a characteristic of each specific radioisotope, and no physical or chemical treatment will alter the half-life of the isotope. Half-lives of isotopes range from microseconds to millions of years.

The March 2011 earthquake in Japan led to a release of radioactive material from the Fukushima nuclear power plant into the atmosphere and ocean. Since the incident, the EPA has been monitoring air, milk, precipitation (rain, snow, and sleet), and finished drinking water for radioactivity. Of the fissure products tested, radioactive iodine (specifically I-131) is the only one found in U.S. drinking waters (http://www.epa.gov/japan2011/rert/radnet-sampling-data.html#water). Radioactive iodine can concentrate in the thyroid, and long term exposure to elevated levels can cause thyroid cancer. However, as of April 4, 2011, the levels of I-131 found by EPA range from undetectable to 2.2 pCi/L and, according to EPA, are all well below levels of concern for public health.

Regulatory Update

Drinking water standards for radionuclides were first set in 1962 and most recently updated by EPA in the 2000 Radionuclides Rule. This rule specifically addresses radioactive radium and uranium, and uses measurements of gross alpha and beta activity as screening methods for a broader range of radioactive compounds such as I-131. The standards are set at 5 pCi/L for combined radium (Ra-226 and Ra-228), 30 micrograms per liter (µg/L) for uranium, 15 pCi/L for gross alpha, and 4 millirems per year (mrem/yr) for beta emitters. Consistent with their use primarily as screening methods, if gross alpha or beta activity measurements are elevated, a more complete analysis will identify specific radioactive isotopes, which could include I-131. EPA has also proposed regulating radon (another commonly occurring radionuclide) in drinking water, but so far no regulation addressing radon in drinking water has been set. The National Research Council published an informative report on radon in 1999, entitled, *Risk Assessment of Radon in Drinking Water*.

Treatment and Removal

Several treatment processes can remove various radionuclides from drinking water sources, as noted in EPA's list of Best Available Technologies for compliance with the Radionuclides Rule and the 2010 Water Research Foundation report, *Evaluation of Gross Alpha and Uranium Measurements for MCL Compliance* (Project/Order #3028). Because naturally-occurring radionuclides are the more typical concern for drinking water sources, they are the primary focus.

Treatment options for radon removal are aeration and granular activated carbon (GAC), with aeration being the most cost effective. Options for removal of radium include ion exchange, lime softening, reverse osmosis, nanofiltration, co-precipitation with barium sulfate, greensand filtration, and GAC. Uranium can be removed by many of the same processes as radium as well as by enhanced coagulation/filtration.

Removal of man-made I-131 was the focus of a study by Summers et al. published in 1989. It found that iodine reacted with aquatic humic substances and concluded that flocculation and activated carbon adsorption were effective for removing the iodine-humic substance complexes. Regardless of whether drinking water utilities are intentionally trying to remove radionuclides from source waters, they can be concentrated in water treatment processes, and the resulting residuals can possibly require special management methods due to the radioactive content. These materials are sometimes referred to as Technologically Enhanced Naturally-Occurring Radioactive Materials (TENORM). The 2005 Water Research Foundation report, *Management of the Disposal of Radioactive Residuals in Drinking Water Treatment* (Project #2695/Order #91077F), helps address and guide efforts in managing drinking water residuals that might contain enhanced levels of radionuclides.

References and Additional Resources

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