U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II
[ADVANCE \x 105]Emergency and Remedial Response Division
[ADVANCE \x 105]Program Support Branch/Technical Support Section
[ADVANCE \x 105]290 Broadway, 18th Floor
[ADVANCE \x 105]New York, New York 10007-1866
Alvey.robert@epa.gov
212 -637-3666

MEMORANDUM FOR RECORD

FROM: **Robert M. Alvey, P.G.**

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SUBJECT: Radium Detections in Groundwater
Long Island, NY and the North Atlantic Coastal Plain

The purpose of this memorandum is to provide basic information regarding detections of radium in groundwater samples collected from Long Island, NY, and the regional context.

What is Radium?

Radium is a naturally occurring element (Ra) and has numerous isotopes. It is a radioactive element formed through the natural radioactive decay of thorium and uranium isotopes. It is the heaviest of the alkaline earth metals and was initially discovered by Pierre and Marie Curie in 1898. It is found in minor concentrations associated with uranium and thorium ores, and occurs worldwide at minor trace levels including in seawater.

Ra ^{226} is the most stable isotope of radium with a half-life of 1600 years. Ra ^{228} has a half-life of 5.75 years. Ra ^{224} has a half-life of about 3.64 days. Radium^{224} is a decay product of Ra^{228}. Radium^{228} can be considered a reasonable proxy indicator for the presence of Ra^{224} in groundwater. The immediate decay product of both of the radium isotopes is radon gas. Radon gas is a colorless odorless, radioactive gas which is responsible for much of the environmental health concerns.

Radium and the Groundwater Regulatory Framework on LI

Nassau and Suffolk Counties became an EPA designated 'sole source aquifer' in June 1978 as the sole or principle drinking water source is obtained only from the groundwater aquifers. All Long Island aquifers receive their fresh water through precipitation, and there are continuous efforts to ensure the adequacy and quality of water is maintained. The Federal Safe Drinking Water requires all states to establish a Source Water Assessment Program (SWAP). NYSDEC is currently updating the SWAP for all of Long Island to address the susceptibility and resiliency of the aquifer system and the drinking water supply. Radium contamination of groundwater is a health issue addressed by the USEPA in its Final Radionuclides Rule, December 8, 2003. This

rule sets maximum contaminant levels (MCLs) for radioactivity. The two radium isotopes identified to be of primary concern are radium^{226} and radium^{228}, due to potential carcinogenic impact. The MCL for combined radium^{226} and radium^{228} was set at 5 pico curies per liter (5 pCi/L). For use as a source of drinking water, the analyses are based on the average of 4 quarterly samples for compliance purposes.

Occurrence of Radium in LI Groundwater

Radium in groundwater under Long Island can generally be attributed to natural sources. Radium can enter the groundwater system by dissolution of minerals or aquifer sediment, desorption from the surface of particles within aquifers, and other processes. According to studies by USGS, detectable radium concentrations exist within the basic soils comprising the North Atlantic Coastal Plain, which includes Long Island.

The aquifer formations beneath Long Island were deposited at different times in the area's geologic history. The deepest aquifer layer, the Lloyd, rests on a bed of consolidated bedrock, primarily igneous and metamorphic. The bedrock was laid down in the Precambrian Era, making it older than 600 million years. The sand deposits of the Lloyd Aquifer were laid down in the Cretaceous Period, about 80-100 million years ago. The sand and gravel of the Magothy aquifer was deposited in the upper Cretaceous Period, about 50-80 million years ago. The youngest aquifer formation, the Upper Glacial, was laid down during the last ice age, which ended roughly 15,000 years ago. It contains some lenses of clay, silt, coarse sands, pebbles, rocks and occasionally boulders, carried to Long Island and left behind by the glaciers.

A higher amount of clay is present where glacial till – unsorted glacial sediment deposits, were formed. The water table, or the top of the groundwater system, is primarily found in the Upper Glacial aquifer. Each of these formations has minute amounts of radium as it is a component of many of the grains. Sands of the Coastal Plain where uranium and radium concentrations tend to be the highest (Zapecza and Szabo, 1986) were directly derived from the continental crystalline rocks as fluvial deposits.

The U.S. Geological Survey (USGS) has conducted several studies regarding the presence of radium in groundwater. Studies were begun in the 1980's associated with similar formations, and a larger study was conducted in the late 1990's concentrating on New Jersey groundwater. The USGS, with participation from the USEPA, conducted a study characterizing the occurrence of radium in groundwater in major aquifers of the United States as part of the National Water-Quality Assessment (NAWQA) Program (Szabo and others, 2012). As part of this study, 1,270 wells were sampled over 15 years (during 1990–2005) and analyzed for Ra^{226}, Ra^{228} and other water-quality parameters. The 2012 Fact Sheet by USGS, "*Principal Aquifers Can Contribute Radium to Sources of Drinking Water Under Certain Geochemical Conditions*" summarizes this effort. The finding of the research indicate:

- Concentrations of Ra^{226} correlated with those of Ra^{228}. Radium^{226} and Ra^{228} occur most frequently together in unconsolidated sand aquifers, and their presence is strongly linked to groundwater chemistry.
- Three common geochemical factors are associated with the highest radium concentrations

in groundwater: (1) oxygen-poor water, (2) acidic conditions (low pH), and (3) high concentrations of dissolved solids.

- Aquifers of the Northern Atlantic Coastal Plain, primarily composed of quartz-rich sand had some of the highest concentrations of radium primarily because of low pH conditions that release radium from the sediments.

Variations in Radium Occurrence in Groundwater

Radium is only moderately soluble in water and only under certain geochemical conditions. Radium can enter groundwater by dissolution of aquifer materials, by desorption from rock or sediment surfaces, and by ejection from minerals during radioactive decay. Studies in New Jersey by USGS in cooperation with the New Jersey Department of Environmental Protection during the 1990's indicated that the chemistry of the water rather than the radium content of the sediment was primarily responsible for higher detections measured.

Shallow groundwater within the NJ study area were statistically found to have higher levels of radium than deeper levels of the aquifer system. This was attributed to effects of "acid rain", which introduces water with a lower pH into the groundwater, and also due to the use of fertilizers. Leaching of nitrogen, calcium, and magnesium from fertilizer and lime applications may increase the mobility of radium in groundwater. Comparisons of ratios of the radium isotopes indicated anthropomorphic sources, such as phosphate-bearing fertilizers, tended to have more radium^{226} than radium^{228} while dissolved radium from naturally occurring minerals in the sands showed more equal proportions.

A positive correlation of higher radium detection and concentrations of nitrate and magnesium was also noted in the USGS study. The sediments comprising the aquifer formations on Long Island contain magnesium. Manganese oxide forms in the sediments, and there is a natural affinity of radium to absorb onto manganese oxide. This affinity results in the concentration of radium in areas where manganese oxide levels are similarly concentrated. Recent research studies at Stony Brook University indicated a statistically higher detection of radon at a coastal area due to the presence on manganese oxide in the sediments which concentrate radium from groundwater discharge. Hydrous manganese oxide is also used commercially as an acceptable treatment technology for radium removal in groundwater supplies.

Suggested Research

The variation of radium levels within the groundwater of Long Island needs further assessment. This constituent is not normally analyzed for in routine monitoring well sample collection. A database of historical and new monitoring results throughout Long Island, including all of the aquifers, would enable potential identification of areas of higher concentration and enable assessment whether health issues are an increasing concern.

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