NATURALLY OCCURRING RADIONUCLIDES IN GEORGIA WATER SUPPLIES: IMPLICATIONS FOR COMMUNITY WATER SYSTEMS

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Abstract. Analytical results of water samples submitted to the Georgia Department of Natural Resources Environmental Protection Division's Drinking Water Compliance Program for naturally occurring radionuclides were used to delineate the spatial distribution of radionuclide detections in Georgia. In community water systems, elevated gross alpha particle activity, elevated radium-226, and elevated combined radium-226 and radium-228 activity have been detected in the Piedmont, Blue Ridge, and parts of the Coastal Plain physiographic provinces.

Current maximum contaminant levels established by the U.S. Environmental Protection Agency are 15 picocuries per liter for gross alpha particle activity and 5 picocuries per liter for combined radium-226/radium-228 activity. These standards were established to reduce the risk of cancer from drinking water containing radionuclides. Of all gross alpha particle activity results, 3.76 percent were above the maximum contaminant level. Of the 955 analytical results for combined radium-226/radium-228, nearly 50 percent were above 5 picocuries per liter.

In Georgia, community water systems could be affected by implementation of new radionuclide regulations that will go into effect in December 2003. In addition to retaining the existing maximum contaminant levels for gross alpha particle activity and combined radium-226/radium-228, the new rule establishes a new uranium maximum contaminant level of 30 micrograms per liter to reduce the risk of cancer and kidney toxicity. Elevated uranium concentrations have been detected in drinking water in the Piedmont and Blue Ridge physiographic provinces. As a result of the new rule, some community water systems with elevated concentrations of natural radionuclides may be required to provide increased monitoring; others may have to implement treatment technologies to meet regulatory compliance.

INTRODUCTION

Naturally occurring radionuclides have long been known to be present in ground water and surface water in Georgia (Cline and others, 1983; Hess and others, 1985; Zapecza and Szabo, 1988; Coker and Olive, 1989). This is a concern for water providers who must meet U.S. Environmental Protection Agency (USEPA) standards (U.S. Environmental Protection Agency, 1976) to reduce the risk of cancer; in some areas, this means increased monitoring and more expensive treatment. Naturally occurring radioactivity in water originates from three different sources. Uranium-238, thorium-232, and uranium-235 in rocks decay to form other radionuclides that can become dissolved in water. Most naturally occurring radionuclides of concern in water are members of the uranium-238 decay series, a 14-step process that ends with lead-206, a stable isotope; however, radium-228 and radium-224 derive from the thorium-232 decay series. Radon-222 is a progeny of radium-226; currently there is no radon-222 maximum contaminant level (MCL); however, a rule has been proposed (U.S. Environmental Protection Agency, 1999).

The purpose of this study is to delineate which areas of Georgia might be vulnerable to the presence of radionuclides in drinking water by using data on record with the Georgia Department of Natural Resources Environmental Protection Division (GaEPD), Drinking Water Compliance Program. A database of analytical results from water samples submitted to the GaEPD from the late 1970s to the present was evaluated. The database contains 14,323 analytical results for gross alpha particle activity, 2,104 results for radium-226, 965 results for radium-228, and 628 results for uranium. Queries of the database were made using U.S. Environmental Protection Agency (2000) MCLs for radionuclides and gross alpha particle activity, and other critical levels established by the GaEPD. Results of the queries were compared to the physiographic province map shown in Figure 1.

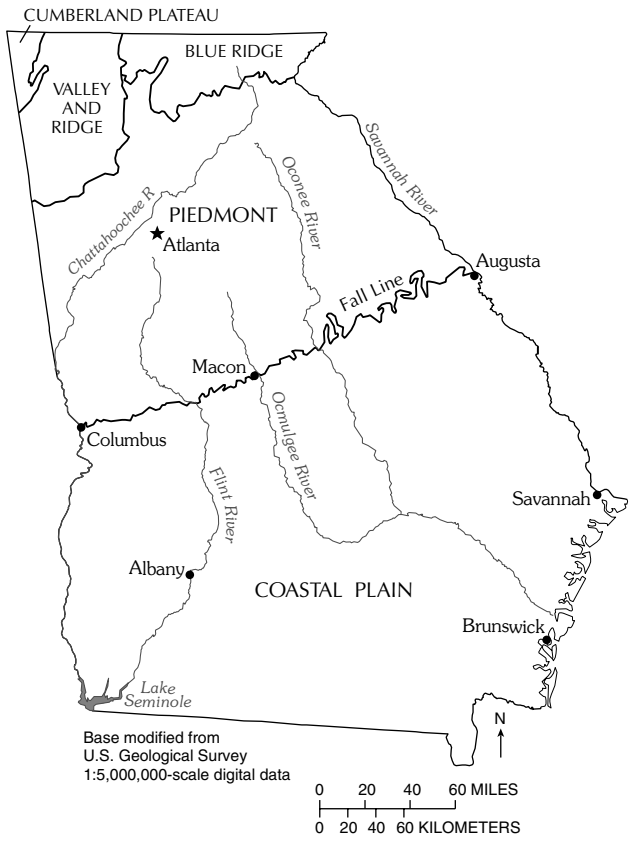

Figure 1. Physiographic provinces of Georgia.

Previous Work

Previous studies have examined the natural occurrence of radionuclides in water in all or parts of the southeastern United States (Michel and Moore, 1980; Cline and others, 1983; Hess and others, 1985; Zapecza and Szabo, 1988; Szabo and Zapecza, 1987; Coker and Olive, 1989; Stone and others, 2002). Michel and Moore (1980) indicated that radium levels in ground water along the Fall Line in the Coastal Plain of South Carolina are due to sands containing uranium and thorium that originated in the Piedmont and Blue Ridge physiographic provinces. Cline and others (1983) reported elevated concentrations of radionuclides in water in Georgia. A map in Zapecza and Szabo (1988) documents high concentrations of radium in Coastal Plain aquifers near the Fall Line.

Szabo and Zapecza (1987) indicated that dissolved oxygen concentration and oxidation-reduction potential are important controls on uranium and radium-226 concentrations in water. Gross alpha particle activity is a measure of the radiation from the decay of alpha-emitting uranium, radium-226, and radon isotopes. Oxidized ground water high in gross alpha particle activity is due to high uranium concentrations. The high gross alpha activity of reduced ground water is due to the high concentration of radium-226.

Coker and Olive (1989) tested 90 wells in Georgia for radon and other radionuclides. Ground water from the granite and gneiss aquifers in the Piedmont contained the highest average concentrations of naturally occurring radionuclides. Stone and others (2002) found elevated levels of radium in drinking water in the "piedmont and coastal plain sandhills" and elevated uranium in water in the "piedmont (and Blue Ridge) region" of South Carolina.

The National Uranium Resource Evaluation (NURE) program, which was conducted to identify uranium resources in the United States, sampled stream sediments and water samples from the lower 48 states and Alaska. From the NURE data, Koch (1988) showed high uranium concentrations in stream sediments in the Piedmont and Blue Ridge. Maps in Hess and others (1985) show population-averaged uranium concentration in surface water (0.35 picocuries per liter—*p*Ci/L) for Georgia exceeds the population-averaged concentration in ground water (0.01 *p*Ci/L).

REGULATORY FRAMEWORK AND COMPLIANCE

By definition, a community water system (CWS) delivers drinking water to at least 15 service connections or to an average of 25 residents, regularly year round (U.S. Environmental Protection Agency, 2000). Currently, CWSs in Georgia are required to test for radionuclides within 2 years of the effective date of the permit to operate (Georgia Department of Natural Resources Environmental Protection Division, 2000) or within 1 year of the introduction of a new water source. Initially, four quarterly samples are taken. If the annual composite or the average of the analyses of these four samples exceeds the MCLs for gross alpha particle activity or total radium, the supplier is required to notify the GaEPD and the public; quarterly sampling then continues until the annual average concentration no longer exceeds the MCL, or until a monitoring schedule, variance, exemption, or enforcement action is effected. The current MCLs established by the USEPA are 15 *p*Ci/L for gross alpha particle activity and 5 *p*Ci/L for combined radium-226/radium-228 (U.S. Environmental Protection Agency, 1976).

On December 8, 2003, a new radionuclide rule (U.S. Environmental Protection Agency, 2000) will take effect. Existing CWSs will have until December 31, 2007, to complete the initial baseline data collection of four consecutive quarterly samples from each entry point to the system for naturally occurring radionuclides (gross-alpha particle activity, radium-226, radium-228, and uranium). New CWSs or new water sources will be required to begin initial monitoring in the first quarter following

the quarter in which the new source or system starts producing water. The new rule will allow the grandfathering of data collected between June 2000 and December 8, 2003, to represent initial data under certain circumstances. Results from this initial baseline data collection effort will be used to: (1) determine compliance with USEPA MCLs; (2) delineate, which radionuclides will be analyzed; and (3) determine future sampling frequency. Flow charts illustrating the monitoring requirements can be found in the USEPA document titled "Implementation Guidance for Radionuclides" (U.S. Environmental Protection Agency, 2002) on the USEPA website at: http://www.epa.gov/safewater/rads/final_rads_implementation_guidance.pdf (accessed November 21, 2002).

GROSS ALPHA PARTICLE ACTIVITY, RADIUM, AND URANIUM OCCURRENCES AND DISTRIBUTIONS IN GEORGIA

Naturally occurring radionuclides have been detected at low levels in many CWSs in most counties of Georgia (Fig. 2*A*). Those CWSs testing high in gross alpha particle activity are in the Piedmont, Blue Ridge, and parts of the Coastal Plain physiographic provinces. This also is true for elevated combined radium-226/radium-228 concentrations. Nearly 50 percent of the water samples analyzed for both radium-226 and radium-228 had combined radium-226/radium-228 concentrations that exceeded 5 *p*Ci/L. Analytical results also show 44 occurrences of combined radium-226/ radium-228 activity greater than 5 *p*Ci/L even when the radium-226 activity was less than or equal to 3 *p*Ci/L (currently, radium-228 testing required when radium-226 is greater than 3 *p*Ci/L).

Gross Alpha Particle Activity

Gross alpha particle activity in water samples exceeding the USEPA 3-*p*Ci/L regulatory detection limit has occurred in most counties in Georgia (Fig. 2*A*). Out of 14,323 total analytical results, 1,443 (10.07 percent) were greater than 5 *p*Ci/L and 539 (3.76 percent) were greater than the MCL of 15 *p*Ci/L. Analytical results greater than 15 *p*Ci/L are clustered in the Piedmont and Blue Ridge physiographic provinces where granites, gneisses, amphibolites, and schists comprise the local petrology (Fig. 2*A*). Another cluster occurs in the Coastal Plain where Miocene phosphatic dolomites are present (Miller, 1986).

Radium-226/Radium-228

Radium occurrence in Georgia (Figs. 2*B*, 2*C*, 2*D*) exhibits a similar pattern to that of gross alpha particle activity (Fig. 2*A*). Combined radium-226 and radium-228 activity greater than the 5-*p*Ci/L MCL was detected in the Piedmont, Blue Ridge, and Coastal Plain physiographic provinces. Out of 955 total combined radium226/radium-228 analytical results, 476 (49.84 percent) were greater than the 5-*p*Ci/L MCL. Some CWSs tested over the combined radium-226/radium-228 MCL for radium-226 alone (Fig. 2*C*). Out of 2,104 total radium-226 analytical results, 367 (17.44 percent) were greater than 5 *p*Ci/L. Counties where at least one radium-228 sample exceeded 3 *p*Ci/L are shown on a map in Figure 2*D*. Out of 915 total radium-228 analytical results, 107 (11.09 percent) were greater than 3 *p*Ci/L. In addition, there were 44 (4.61 percent of combined total) occurrences indicating combined radium-226/radium-228 concentrations greater than 5 *p*Ci/L when radium-226 concentrations were less than or equal to 3 *p*Ci/L (regulatory detection limit).

Uranium

Elevated uranium concentrations in CWSs have been detected in water samples from the Piedmont and Blue Ridge physiographic provinces. Counties where at least one sample was greater than 30 micrograms per liter (µg/L) are clustered in the Piedmont and Blue Ridge (Fig. 2*E*). Out of 628 total uranium analytical results, 192 (30.57 percent) were greater than 27 *p*Ci/L (30 µg/L). Seven counties had at least one sample containing a uranium concentration greater than 270 *p*Ci/L (300 µg/L), or 10 times the new USEPA MCL of 30 µg/L.

Based on data collected under the NURE program and presented in Koch (1988), areas containing elevated uranium concentrations in stream sediments occur in the same provinces as those showing elevated dissolved uranium concentrations in community water supplies. This suggests that uranium is not exclusively a component of ground water but can also occur in surface-water supplies.

Results presented in this study generally agree with the previous research of Stone and others (2002), who examined uranium and radium occurrences in South Carolina, and the work of Zapecza and Szabo (1988), who mapped zones of elevated dissolved uranium, radon, and radium concentrations in ground water, using data from other sources. Michel and Moore (1980) suggested that the source of radium in the Coastal Plain of South Carolina is sediments originating from crystalline rock of the Piedmont. Some counties in south-central Georgia where radium concentrations are elevated lie within an area of known phosphate concentration (Georgia Department of Mines, Mining, and Geology, 1969). Some of these phosphates are known to contain uranium and radium (Cline and others, 1983).

Figure 2. Naturally occurring radionuclides in community water systems in Georgia (Data source: Georgia Department of Natural Resources, Environmental Protection Division, Drinking Water Compliance Program).

CONCLUSION

The presence of naturally occurring radionuclides across substantial areas of Georgia raises concern for local water suppliers who derive water from either surface- or ground-water sources or from a combination of both. Under the new USEPA radionuclide rule, community water systems operating in areas of known radionuclide occurrence will need to continue to evaluate radionuclide levels and may be required to perform increased sampling and analysis, and possibly, additional treatment to comply with regulations. Perhaps the area of greatest concern is in the Piedmont, where uranium concentrations will need to be monitored, as well as other naturally occurring radionuclides. In some cases where radionuclide concentrations are high, remediation technologies may be needed to comply with regulatory limits (U.S. Environmental Protection Agency, 2000).

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