URANIUM, RADIUM, AND RADON IN WELL WATER IN SOUTH CAROLINA: DISTRIBUTION AND PROBLEMS

Peter A. Stone[1], Robert J. Devlin[1], Bruce Crawford[1], and David G. Baize[2]

AUTHORS: [1]Hydrologist/Geologist, [2]Director, Bureau of Water, South Carolina Department of Health and Environmental Control, Columbia, SC 29201
REFERENCE: *Proceedings of the 2005 Georgia Water Resources Conference*, held April 25-27, 2005, at The University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia

INTRODUCTION

South Carolina, despite being a small state, possesses a wide range and diversity of hydrogeologic conditions, generally arranged into geologic belts or physiographic provinces. These distinct areas range from the mountains and piedmont with crystalline metamorphic and igneous rocks with major geologic structural features, to a broad coastal plain with sand and limestone aquifers (Fig. 1). Accompanying this physical diversity are some special problems and risks to ground-water users of each region, all of which must be recognized in statewide ground-water and drinking-water management. One type of risk to users that has strong geographical associations is the scattered—but not random at the state scale—problems of natural mineral-derived radioactive elements dissolved in the ground water, problems that are significant both numerically (by number of wells) and susceptible area (in toto) . Here a problem means concentration above the US EPA drinking water standard. Essentially, the overall problem exists mainly as uranium in excess in parts of the piedmont and its border in the Appalachian "foothills" and radium in excess in inner parts of the coastal plain. Some outliers and other local problem areas also exist and are important though. Radon at potential problem levels is wider spread. Main concern with uranium, radium, and radon is for home wells, because public supply wells have been or will be tested routinely and any problem has been or will be identified and eliminated. A problem, even a severe one, may exist and persist unknown in home wells for decades or occasionally generations.

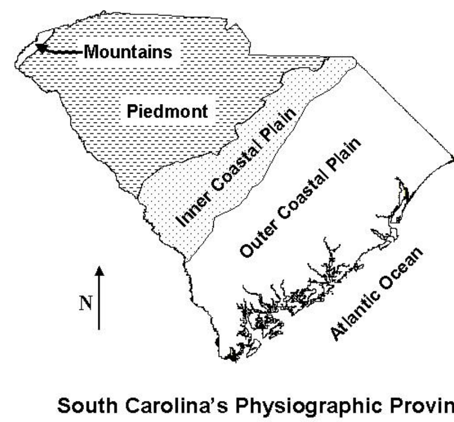

Figure 1. Main physiographic, geologic, and hydrologic provinces of South Carolina

URANIUM PROBLEMS AND DISTRIBUTION

Uranium is radioactive and its concentration is normally considered as one of the radiological characteristics of well water, but its lowest concentration of health concern is instead related to being a toxic heavy metal (EPA drinking water limit is 30 µg/L or parts per billion). Uranium has been found at concentrations above 30 µg/L at a number of widely scattered sites in middle and innermost parts of the piedmont (including the mountain-fronting "foothills" area) and in at least one substantial (neighborhood-sized) cluster of wells. Virtually all of these sites involve rock wells that tap fractures in crystalline rock and most appear to lie in areas of felsic (essentially light-colored) metamorphic rock (e.g., gneiss) or granite, both common of the piedmont. The most troublesome cluster, located in the middle piedmont (near Simpsonville), has some wells with very high to extremely high concentrations (e.g., >100 to >300 times the drinking water limit, up to ca. ["circa" or "about"] 10 mg/L or parts per million). This is in an area of only slightly metamorphosed granite but has a water chemistry that in some wells is far different from that expected from granite. The water is relatively rich in dissolved-minerals and shows evidence of contact with carbonates. These are also the wells of highest uranium content, thus some peculiar geological condition exists here in addition to excessive soluble uranium minerals exposed to fractures. Oddly, this relationship does not hold for the more scattered wells elsewhere in the region showing high uranium concentrations. This suggests there are multiple types of sources or causes. Fortunately, a survey investigation of several other large granite areas (10+ km across) revealed no other problem area or even a common occurrence of isolated problems.

No high uranium concentrations were found in large-diameter regolith wells within the cluster area, even though the regolith is directly derived from the bedrock. The uranium source is thus believed to be down in the hard rock, not derived from the weathering of the top of the granite. A deep core of the rock near two extreme-problem wells did not show any extraordinary uranium concentration or source but did reveal distinct uranium enrichment as a film on one water-yielding fracture face. The film was also associated with some underlying carbonate, existing as a fractured carbonate vein or a fracture coating of carbonate. In similar manner the ultimate sources to wells may be highly localized, which could explain the extreme local variability even within the problem neighborhood (acceptable wells and extreme-problem wells lie within short distances of each other). This condition of high local variability makes simple survey sampling less reliable—or at least less straightforward—in any attempted use as a confident predictor or detector of additional problem areas.

The regional occurrence of uranium at problem concentrations is in the piedmont and its border with the mountains, but the tighter geographic distribution in places suggests an association with major geologic features (perhaps with metamorphic belts or fault zones) and sometimes with an unusual geochemistry beyond just the uranium. An important remaining concern is that other small and hard-to-find areas of high uranium concentration exist. These areas could be similar to the area of extraordinarily high concentration which itself was missed in broad surveys with wider spaced (ca. 7-8 km) sampling 25 years ago (National Uranium Resource Evaluation: Smith, 1997). The concern, of course, is that wells in unknown uranium problem areas are being or will be used for home drinking water. Wider survey testing is still being undertaken in an attempt to find anomalous areas where more intensive surveying would be justified. A university effort (University of South Carolina, Clemson University, Furman University) is underway to better understand, predict, and find any additional problem areas.

RADIUM PROBLEMS AND DISTRIBUTION

Radium at problem levels is found mainly in sand aquifers of the inner coastal plain, that landward portion lying nearer the piedmont. The drinking water limit for radium is given in radioactivity, not concentration (5 pCi/L as the total for the two separate isotopes ^{226}Ra and ^{228}Ra, where pCi is "picocuries" and "pico" represents 10^{-12}). Radium is a carcinogen by its radioactivity.

Radium problems occur both as isolated occurrences (in individual wells) and as areal clusters of neighborhood to small-town size. A few wells have radium at levels 5-15 times the health limit for drinking water, but none has been found with the extreme values that several wells show with uranium (>100 times). The occurrence of scattered radium problems, and even clusters, has long been known but were thought to be very isolated and rare, because public-supply whole-system testing did not show a high incidence. Expanded (specific well) monitoring has recently shown the problem to be much more common than once thought. Again, the main concern now is with the many thousands of home wells that are not routinely tested. Having to measure the two isotopes separately, by their radioactivity, makes testing expensive and thus limited.

The available sampling indicates that radium problems are more common, and more clustered, toward the southwest, in the half of the inner coastal plain closer to Georgia. Sometimes a local radium problem may be vertically isolated, such that a deeper well and aquifer or even aquifer zone in the same aquifer system is without the problem and yields acceptable water. Several towns have drilled a deeper well at the same location as an existing well with high radium.

Gamma logging at problem wells has not yet identified any zone of dramatically higher radioactivity that would be suspected as the source. Deposits causing the problem may not be laterally extensive. This is also suggested by the high variability in radium concentration sometimes seen over short lateral distances. The inner coastal plain is notoriously heterogeneous geologically at this scale. Areal survey data are thus not very predictive, even in the close vicinities of the tested wells. Most importantly, areal surveys cannot confidently predict the absence of a problem.

The ultimate source of the radium is uranium and thorium, radioactive elements in minerals of the sands (or clays) which "decay" radioactively to radium and eventually to radon. Studies show that the mineral sources must lie fairly nearby, because short-lived daughter isotopes are present in the well water (Michel and Moore, 1980). The local variability in some areas likely indicates areally-segregated source sediments. The scattered and unexplained distribution of some problem wells challenges the ability to predict or find other problem wells by data from better (larger or "tighter") surveys or by geologic associations. It may be possible to identify broad but smaller-than-county-size areas where sampling is highly warranted and to develop reliable but cheaper screening criteria. Initial testing suggests that gross-alpha measurement has promise in cheaply identifying wells with radium at the greatest problem levels, but probably cannot identify "safe" wells with any high degree of confidence.

RADON PROBLEMS AND DISTRIBUTION

Radon at potentially problem levels in ground water is common and widespread in the mountain and piedmont regions and also occurs in places in the inner coastal plain. There are also potential radiological problem areas near the coast, perhaps especially near the phosphate-rich areas (suggested by radon in home air and other background surveys). The situation with radon is not well understood yet because no standard has been set and widespread testing is not yet mandatory for public-supply systems

TREATMENT

Uranium and radium are relatively easy and inexpensive to treat in a home setting, by off-the-shelf technology widely available in home-improvement stores (ion exchange, water softening, reverse osmosis) or from contractors (http://www.scdhec.net/eqc/water/html/urtreat.html). The technology exists for a similar solution for radon.

CONCLUSIONS

Uranium and radium at concentrations of health concern are found in well water at widely scattered sites, and in some clusters, mainly in the piedmont (plus mountains) and in the inner coastal plain, respectively. Radon at problem concentrations seems to be more common, but mainly in the same geologic provinces.

REFERENCE CITED

Michel, J., and Moore, W.S., 1980. ^{228}Ra and ^{226}Ra content of groundwater in Fall Line aquifers. *Health Physics* 38: 663-71.

Smith, S.M., 1997. National geochemical database—reformatted data from the National Uranium Resource Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) program. *U.S. Geological Survey Open-File Report* 97-492 http://water.usgs.gov/pubs/of/1997/ofr-97-0492/

Additional information:
http://www.scdhec.net/eqc/water/html/gwrads.html (Radionuclides)
http://www.scdhec.net/eqc/water/html/uranium.html (Uranium)
http://www.scdhec.net/eqc/water/pubs/cr001602.pdf (Radium)