

WHAT WE KNOW ABOUT URANIUM AND RADON GEORGIA WELL WATERS

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Abstract

Radionuclides from three naturally occurring decay series, headed by ^{238}U , ^{232}Th , and ^{235}U , have long been known to be present in groundwaters in Georgia. In 2010, routine surveillance of drinking-water testing revealed uranium concentrations exceeded the U.S. Maximum Contaminant Level (30 ppb) in some private wells in central Georgia. High levels of uranium in well water may be associated with elevated levels of dissolved radon gas since they are in the same ^{238}U decay series. Drinking water that contains high levels of these contaminants can have adverse health consequences, though definite relationships of those health issues with uranium and radon in drinking water have not been established. This paper provides an overview of our testing, mapping programs, and public education programs for tracking and mitigating uranium and radon in Georgia well waters. It also sheds some lights on the temporal variation of these two contaminants in well waters and their interrelationships.

Introduction

Radiation exposure from naturally occurring radionuclides in drinking water sources may result in various public health concerns. In this regard, alpha radiation emitted by uranium, radium, and their progenies, including radon are particularly important. The World Health Organization (WHO) suggests that when the radioactivity in drinking water exceeds the recommended level of 0.5 Bq/L (or 13.5 pCi/L) for gross-alpha (α) or 1 Bq/L (or 27 pCi/L) for gross-beta (β) activities, radionuclide-specific concentrations should be brought into compliance with WHO guidance levels: 0.1 Bq/L for ^{228}Ra ; 1 Bq/L each for $^{223-226}\text{Ra}$, ^{234}U , and ^{235}U ; 10 Bq/L for ^{238}U ; 100 Bq/L for ^{222}Rn , and 15 $\mu\text{g/L}$ for total uranium (WHO 2004).

Human body can rapidly eliminate 66% of absorbed uranium through urine ((Wrenn et al., 1985). However, the rest get distributed and stored in the kidney (12–25%), bone (10–15%), and soft tissues (Wrenn et al., 1985). Radium accumulates primarily in the bone (Wrenn et al., 1985). Ingested uranium primarily causes renal impairment by chemical toxicity (Zamora et al., 1998; Zamora et al., 2009); whereas ingested radium and radon causes carcinogenic effects via radiotoxicity (Wrenn et al., 1985).

This study was partially funded by The University of Georgia Radon Education Program which is supported by Georgia Department of Community Affairs through funding from State Indoor Radon Grants (SIRG) program of The United States Environmental Protection Agency, Region-4.

Once ingested with water, radon gas diffuses into the stomach wall and irradiates the stomach wall tissues and can cause stomach cancer (Hopke et al., 2000). Inhaled radon from indoor air is known to cause lung cancer (Darby et al., 2005).

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Radionuclides from three naturally occurring decay series (headed by ^{238}U , ^{232}Th , and ^{235}U), have long been known to be present in ground water and surface water in Georgia (Cline et al., 1983; Hess et al., 1985; Zapecza and Szabo, 1988; Coker and Olive, 1989). In a previous study, Albertson (2003) found elevated gross alpha particle activity, elevated radium-226, and elevated combined radium-226 and $^{228}\text{Radium}$ activity in some community water systems in the Piedmont, Blue Ridge, and parts of the Coastal Plain physiographic provinces of Georgia. Elevated uranium concentrations were detected in drinking water in the Piedmont and Blue Ridge physiographic provinces (Albertson, 2003). Coker and Olive (1989) tested 90 wells in Georgia for radon and other radionuclides and concluded that groundwater from the granite and gneiss aquifers in the Piedmont contained the highest average concentrations of naturally occurring radionuclides. Stone et al. (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.

In 2010, routine water testing of some private drinking water wells at Agricultural and Environmental Services Laboratories (AESL) revealed high levels of uranium with concentrations above EPA's maximum contaminant levels (MCLs) of 30 parts per billion (ppb; 20 pCi/L). These wells were located in specific areas of the state. High level of uranium in well water was often associated with a high level of radon gas measured in air by the homeowner (Lynch et al., 2016). Uranium and radon in deep wells originate from naturally occurring granitic bedrock located primarily in the Piedmont and Blue-Ridge (PBR) regions of Georgia (Albertson, 2003). The residents in the areas affected by high uranium and radon in well water reported to various agencies numerous health problems, including cancer, kidney problems, autoimmune disorders, gastrointestinal symptoms, and neuropathy although there has not been any report directly linking these contaminants and illnesses. Conversations with residents and county officials established a need for more public education, testing, and informational resources. From 2010 to 2013, the University of Georgia Cooperative Extension conducted a public education program along with a half-price water testing service to encourage well owners to test their waters. The intent was to expand the database to better understand the nature and extent of the problem and increase public awareness in this regard. In 2015, the AESL and The College of Family and Consumer Sciences of the University of Georgia launched a new Radon in Household Water Testing and Education program. This paper reports an up-to-date summary of the testing and education programs on uranium and radon in Georgia household well waters with special reference to:

1. Mapping uranium and radon concentration in private drinking water wells based on voluntary submission of samples by the well owners.

2. Temporal variation in uranium and radon in Georgia well waters.
3. Impact of public education programs on a) peoples’ consideration of water testing for uranium and radon, b) enhancement public awareness about these contaminants, and c) the engagement of community advocates in protecting public health.

What We Know So Far?

Testing and mapping uranium and radon in Georgia well waters

The half-price testing service resulted in a substantial increase in voluntary submission of water samples for testing these contaminants, which in turn, enhanced our understanding about the nature and extent of the problems in the state. The testing program has been still continuing, but at a full price.

As of July 20, 2018, the total number of water samples tested for uranium was 1305 (Table 1). Of these, 158 had detectable amounts of uranium (above 10 ppb) with 71 being above the EPA’s 30 ppb Maximum Contaminant Level (MCL). One of the wells tested as high as 6297 ppb, which is more than 200 times greater than EPA’s MCL for uranium for public water supplies. Of these 71 samples, as many as 70 were from the Piedmont Blue Ridge Regions above the “Fall Line” (Figures (1) and (2)).

Table 1. Total number of wells for uranium and radon and summary of the test results.

Household Wells Tested	Detectable	Above MCL	Range Above MCL
<u>Uranium (µg/L)</u>			
1305	158	71	30.1-6,297
<u>Radon (pCi/L)</u>			
177	175	130	311-69,709

The testing program for radon in water at AESL began on August 26, 2015. As of July 20, 2018, 177 well waters were tested for radon. Of these, 175 had detectable level of radon (100 pCi/L) with 130 exceeding the proposed MCL (300 pCi/L) and 18 exceeding the Alternate MCL (AMCL: 4000 pCi/L). Of the 130 wells with radon levels above MCL were from the areas above “Fall Line” (Figure (4)).

The AESL developed a mapping program for uranium and radon in well waters and made it available online for public at <http://aesl.ces.uga.edu/water/map/>. The mapping program updates the maps as the new results are added to the AESL database. It allows the users to select various options and generate maps as per their choice. Some examples maps are presented in Figures (1)-(4).

Figure (1) shows the locations of all 1305 wells tested for uranium until July 20, 2018.

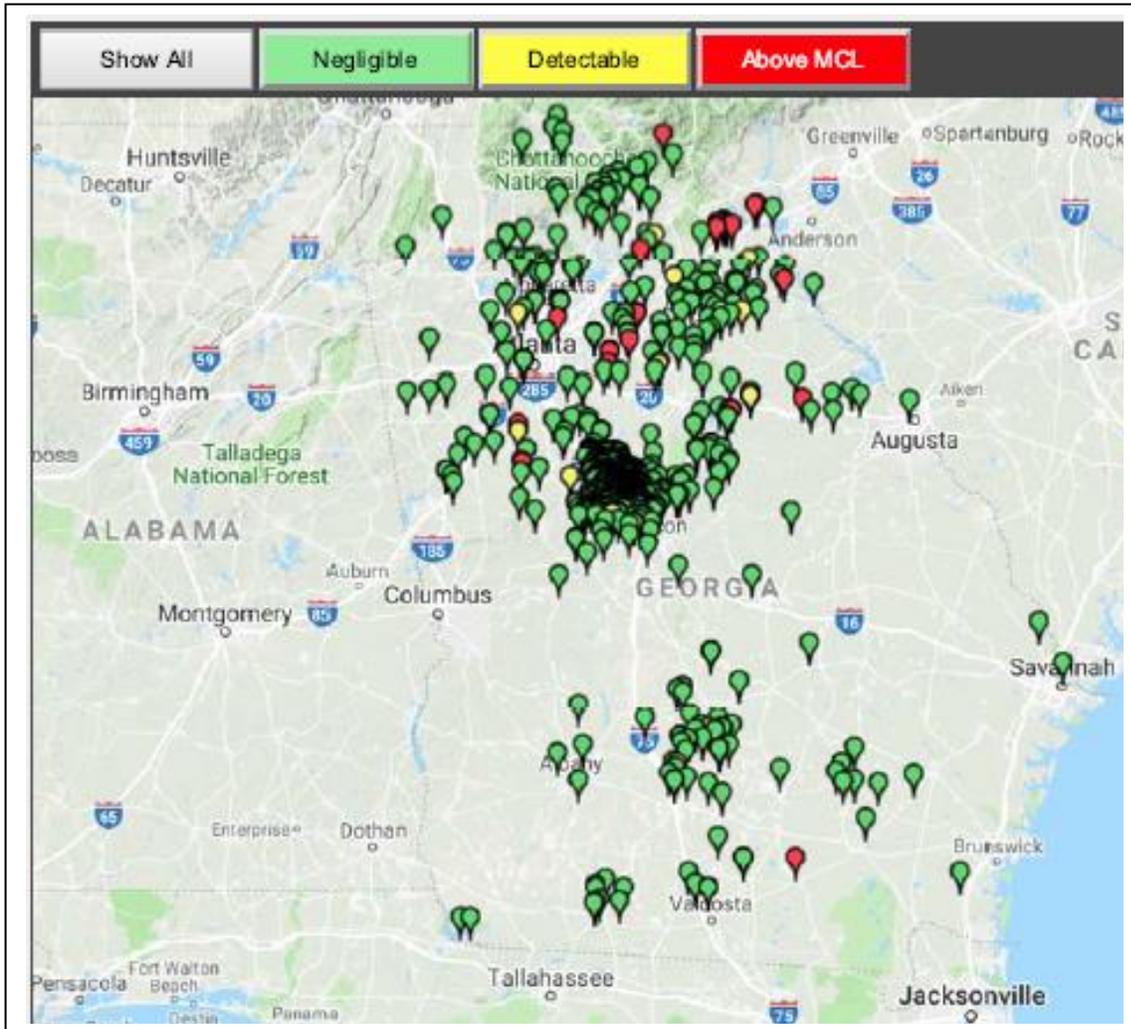


Figure (1): Distribution of 1305 well water samples tested for uranium at Agricultural and Environmental Services Laboratories (AESL), University of Georgia (UGA) from 03-20-2008 to 07-20-2018.

Figure (3) shows the locations of all 177 wells tested for radon until July 20, 2018.

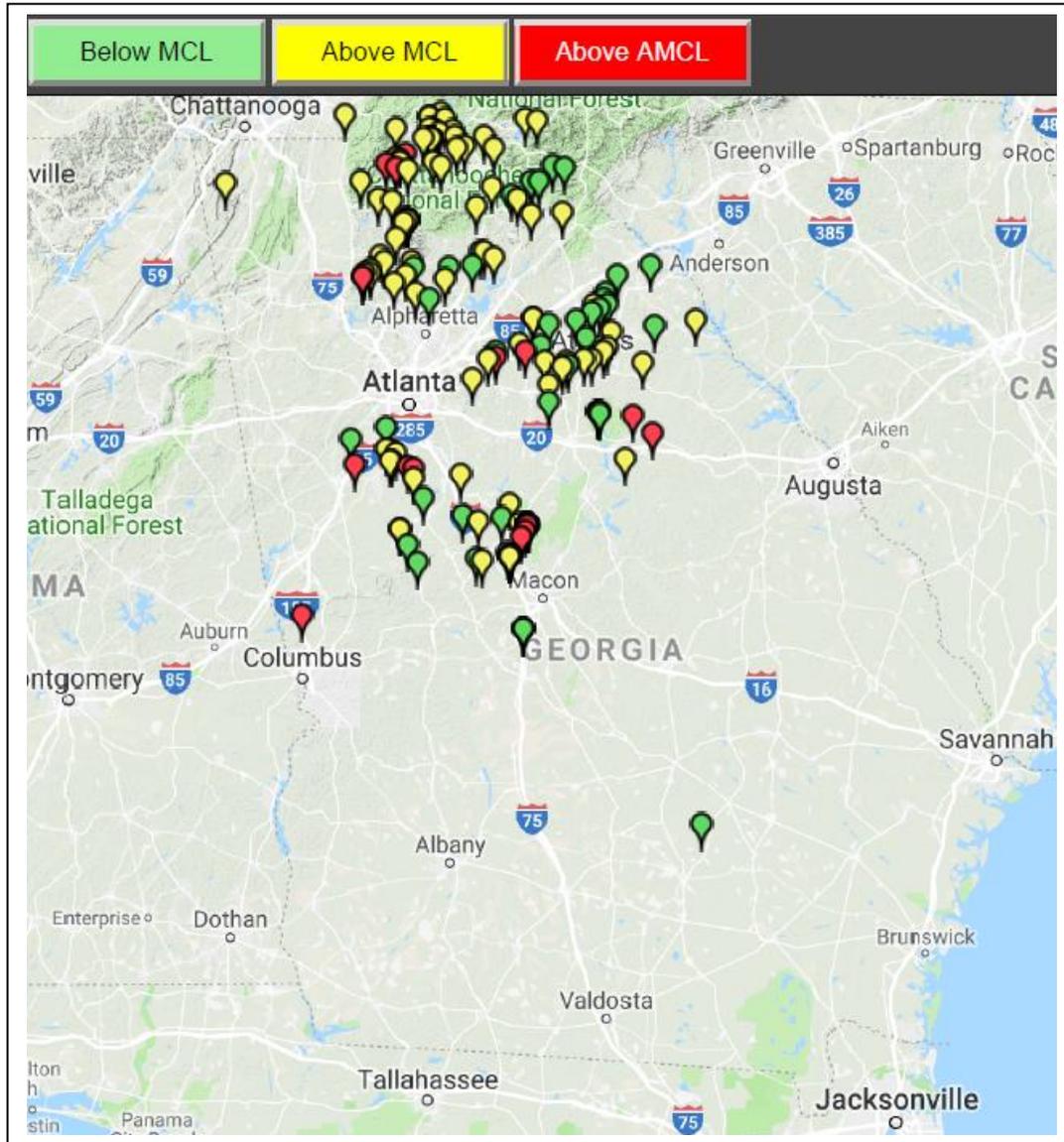


Figure (3): Distribution of well water samples tested for radon at Agricultural and Environmental Services Laboratories (AESL), University of Georgia (UGA) from 08-26-2015 to 07-20-2018.

Figure (4) shows the locations of all 130 wells (in yellow) that had radon concentration above proposed Maximum Contaminant Level (300 pCi/L) but below the proposed Alternate Maximum Contaminant Level (300-4000 pCi/L) level and 45 wells that had radon concentration higher than proposed Alternate Maximum Contaminant Level (>4000 pCi/L).

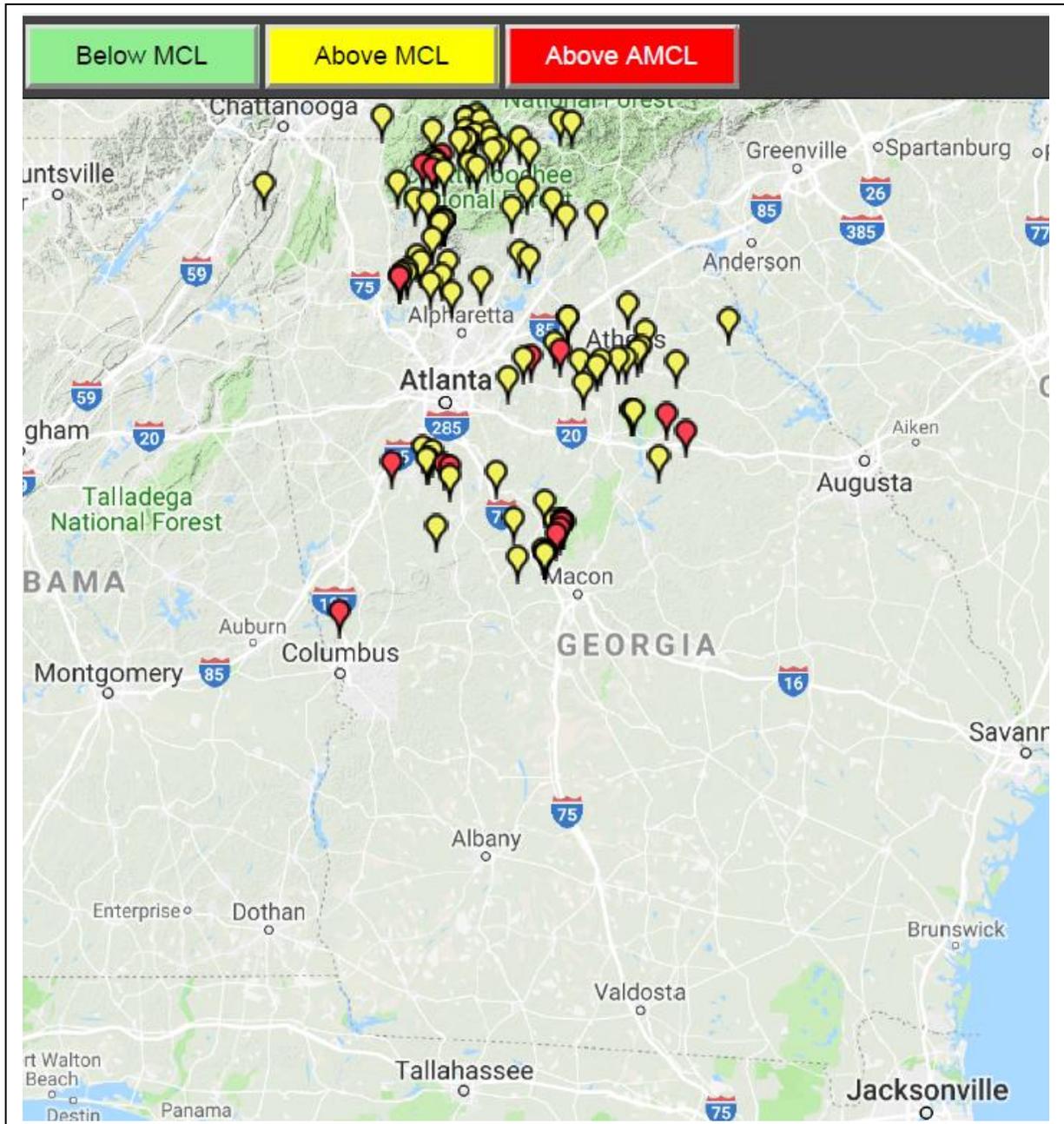


Figure (4): Distribution of well water samples with radon levels that are higher than the proposed MCL (100 pCi/L) or AMCL (4000 pCi/L) for drinking water (based on the test performed during 08-26-2015 to 7-20-2018 at AESL, UGA).

Temporal variation of uranium and radon concentration in the same well

Apart from evaluating the test results of uranium and radon in household well waters received from voluntary submission by the well owners, we conducted an independent study of these two contaminants in four wells namely “Well-6090DFR”, “Well-711JPR”, “Well-715JPR”, and “Well-578TR”. When the same three wells were sampled and analyzed for radon on two different dates (28 May, 2016 and 16 June, 2016), we obtained remarkably different radon concentrations for the two different dates in any given wells (Figure (5)). Such results suggest that temporal variation in radon concentration in the well waters is significant and should be duly considered for determining the actual overall exposure to radon from water of the household members.

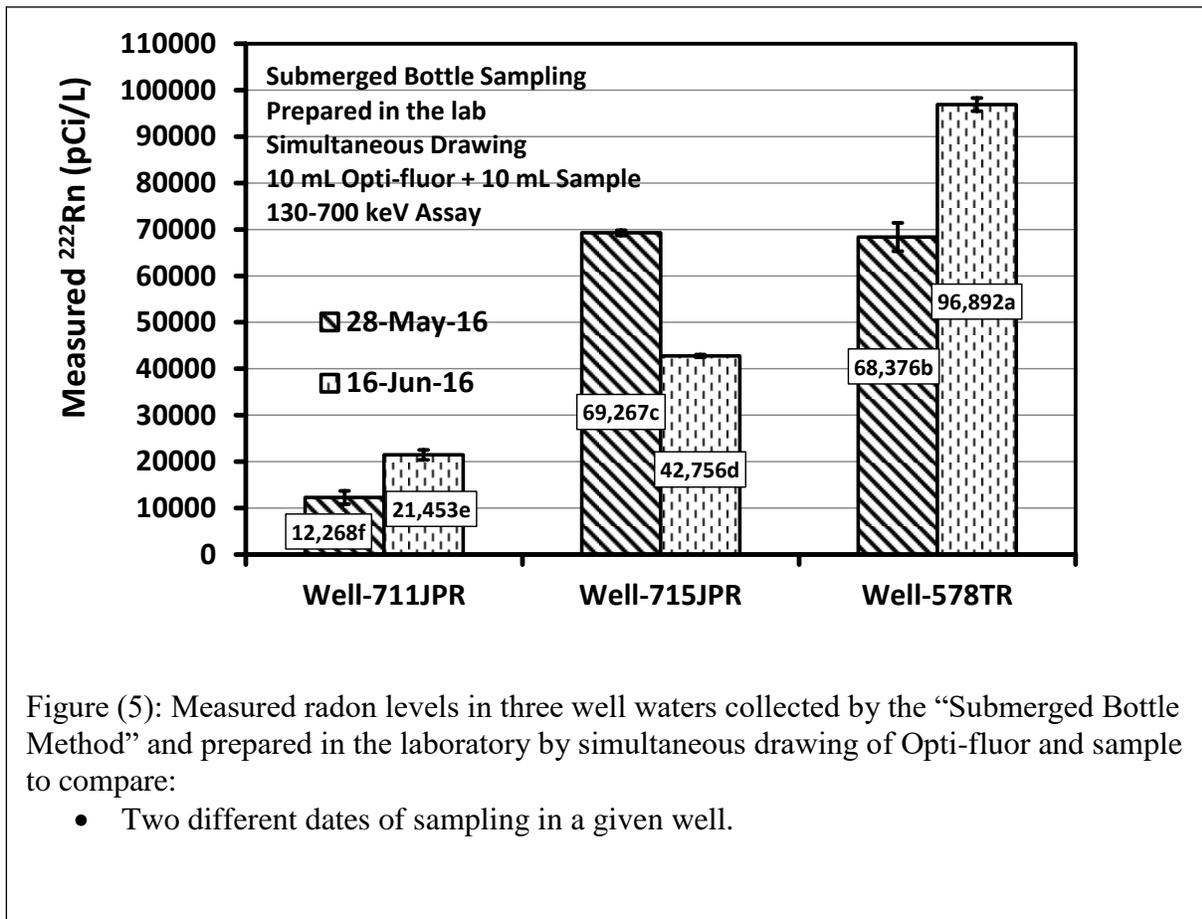


Figure (5): Measured radon levels in three well waters collected by the “Submerged Bottle Method” and prepared in the laboratory by simultaneous drawing of Opti-fluor and sample to compare:

- Two different dates of sampling in a given well.

Out of the four wells, three wells (“Well-6090DFR”, “Well-715JPR”, and “Well-578TR”) had uranium concentration much higher than the EPA’s drinking water MCL (Table 2). The uranium level in the “Well-711JPR” was below the MCL. However, all four study wells had radon concentrations much higher than the EPA-proposed MCL of 300 pCi/L as well as the proposed alternate MCL (AMCL) of 4000 pCi/L. Furthermore, the radon concentrations followed the same trend as the uranium concentrations in the wells. Nevertheless, it is important to note here that despite there was no concern about the uranium concentration (22.6 ppb) in the “Well-711JPR”, it contained well over 20,000 pCi/L radon. Therefore, using uranium concentration over 30 ppb as a trigger for recommending test for radon in well water

remains questionable. We also noticed temporal variation in the uranium concentration in the “Well-6090DFR” and “Well-578TR”. Such variation was significant in the case of “Well-578TR” (1,549 ppb in June, 2001 versus 4,939 ppb in June, 2016)

Table (2): Concentration of uranium in the four wells.

Well	Date	Uranium Conc. (ppb) [‡]	Comment	Date	Uranium Conc. (ppb)
Well-6090DFR	3 March, 2016 [†]	542	Sampled by U. Saha	14 June, 2011 [§]	629
Well-711JP	20 June, 2016 [†]	22.6	Sampled by D. Lynch		
Well-715JP	16 June, 2016 [†]	407	Sampled by U. Saha		
Well-578TR	16 June, 2016 [†]	4,939	Sampled by U. Saha	15-June, 2011 [§]	1,549

[†]Sampled and analyzed as part of this study. [‡]EPA’s MCL for drinking water is 30 ppb. [§]Voluntary submission by the well owner.

Health Risk from Radon in Household Water

Once radon-rich water is ingested, radon gas diffuses into the stomach wall and irradiates the stomach wall tissues and can cause stomach cancer (Hopke et al., 2000). Inhaled radon from indoor air is known to cause lung cancer (Darby et al., 2005). Radon in household water supply poses both inhalation and ingestion risks. Most risk from radon in water comes from radon released into the air when water is used for showering, laundering, and other household purposes. According to USEPA (2012), the risk of lung cancer from inhaled radon from air is much larger than the risk of stomach cancer from ingesting water with radon in it. A *very rough rule of thumb* for estimating the contribution of radon in household water to indoor air radon is that water with 10,000 pCi/L of radon contributes about 1 pCi/L to the level of radon in the indoor air. Based on a National Academy of Sciences report (NAS, 1999) on radon in drinking water, EPA estimates that radon in drinking water causes about 168 cancer deaths per year, 89% from lung cancer caused by breathing in radon released from water, and 11% percent from stomach cancer caused by ingesting drinking radon-containing water.

We evaluated the results a week-long continuous radon monitoring in the indoor air of a Georgia home with 629 ppb uranium and 79,012 pCi/L radon in the household well water. The average indoor radon level was 5.8 ± 0.2 pCi/L. However, the indoor air radon level increased up to 14.4 pCi/L during showering and/or laundering, suggesting 8.6 pCi/L increase from the average concentration of 5.8 pCi/L (Figure (6)). According to the well-known rule of thumb, a 79,000 pCi/L radon in household water has a potential to elevate the indoor air radon concentration by 7.9 pCi/L. Interestingly this corresponds fairly well with the observed elevation of 8.6 pCi/L.

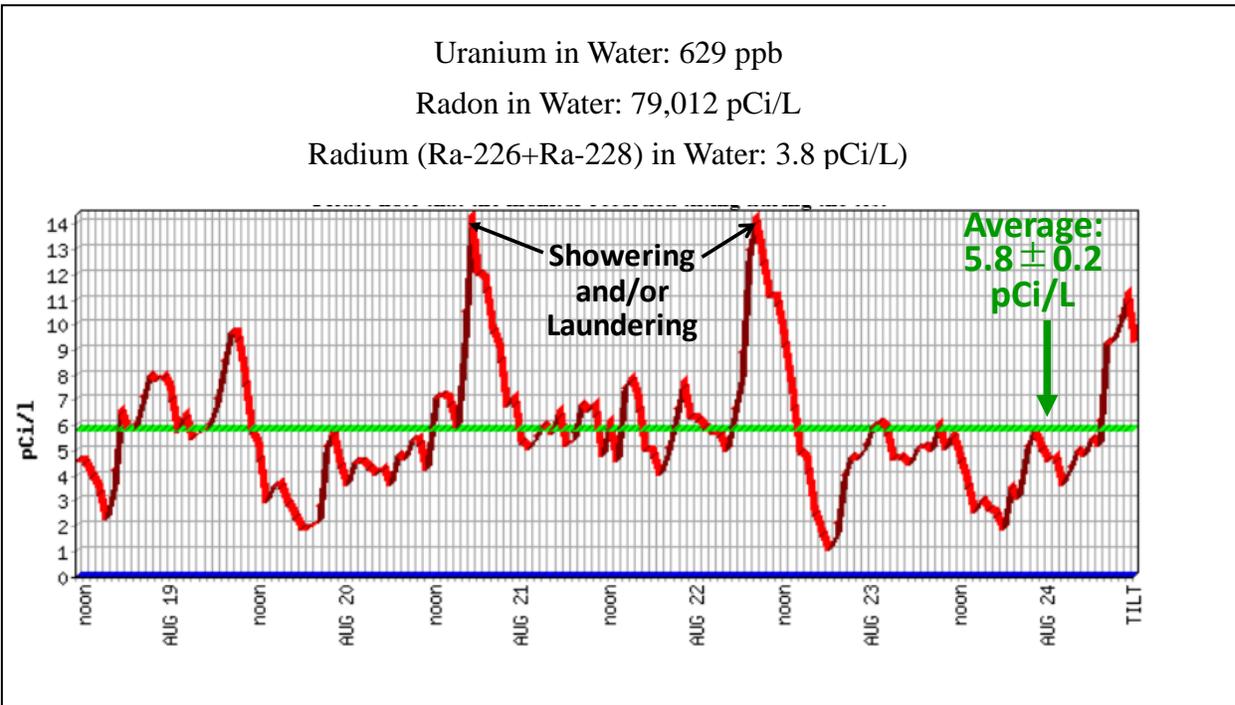


Figure (6): Results of a week-long radon monitoring in the indoor air of a Georgia home with high levels of uranium in household well water.

Community engagement in mitigating uranium and radon in well water

In 2010, routine water testing revealed high uranium concentrations exceeding EPA's maximum contaminant levels (MCLs) of 30 parts per billion (ppb) in some private drinking water wells in central Georgia. High level of uranium in well water was often associated with a high level of radon. Uranium and radon in well water originate from naturally occurring granite bedrock. Drinking water that contains high levels of these contaminants can have adverse health consequences. County residents reported numerous health problems, including cancer, kidney problems, autoimmune disorders, gastrointestinal symptoms, and neuropathy. Residents and local officials expressed the need for more public education, testing, and informational resources.

Several public education workshops were conducted primarily in Monroe and Bibb counties, which are located in central Georgia. The 1- to 3-hour workshops were attended by 25 to 500 county residents. The objectives of the workshops were: (1) Educate consumers about uranium and radon, (2) Promote testing household water for uranium and the air for radon; and (3) Provide information on treatment systems to remove these contaminants. Post workshop survey showed overwhelming positive response from over 90% of the attendees in terms of knowledge gained and ability to handle well water problems. To encourage testing, households were offered free radon air sampling kits and half-price uranium water testing. Extension fielded questions from various stakeholders (well owners, health department and social workers, journalists, public officials) to allay concerns and clarify issues. Homeowners with homes testing high radon in air were encouraged to test their water for radon. In some instances, test data showed that there were areas with very high levels of uranium (as high as 6297 ppb) and radon (as high as 70,000 pCi/L) in water. Such high concentration cannot be removed by a common household water treatment

system. The only viable option for those affected was to obtain their water supply from the public water system or move out of the affected areas and abandon their homes (losing 100% of their home equities). However, extending county water distribution lines to areas with high uranium and radon required a multimillion-dollar investment.

Our program laid out the evidence-based groundwork that led to increased collaboration with state health and environment agencies, EPA, and community advocates that resulted in the county securing financing to extend water lines to the areas of the county impacted by contaminated well water. The project is complete, and the community is now connected to the county water supply system. See the news at: <http://www.macon.com/news/local/article30142776.html>. The program has enhanced our understanding about the nature and extent of uranium and radon problems in the state and how we can make an even greater impact by engaging with community advocates and various stakeholders. The program has also made a significant impact by educating homeowners and improve their knowledge on determining appropriate mitigation strategies, thereby creating a healthier environment and improve their quality of living.

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