Progress in Testing, Public Education, and Mitigation of Radon in Indoor Air and Well Water in Georgia During Last 10 Years

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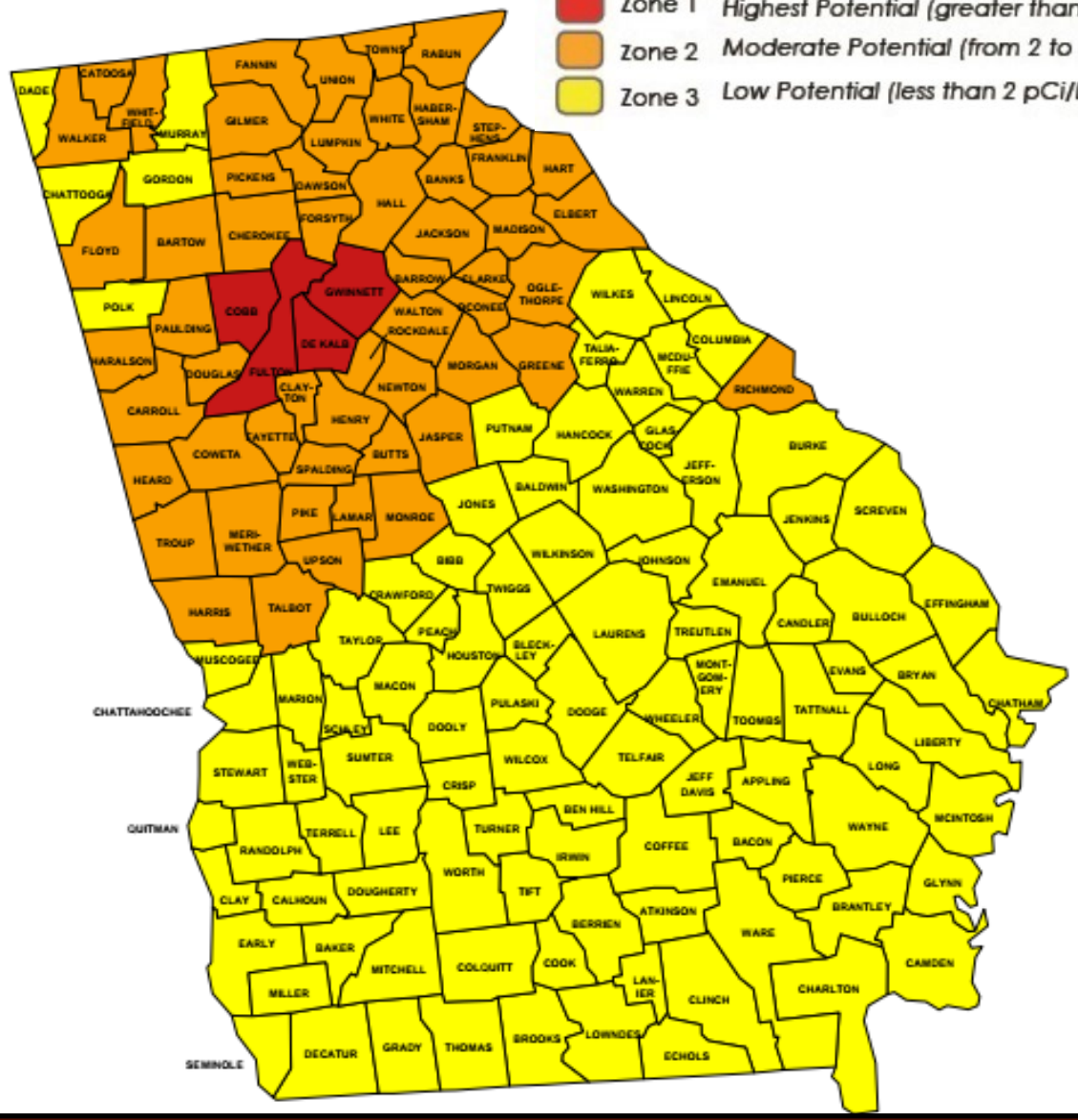
OUTLINE

- **Mapping of radon in both indoor air and well water**
- **Bivariate associations between the physiographic provinces and the proportion of indoor air radon concentration above 4.0 pCi/L**
- **New initiatives to increase testing, public awareness, and mitigation of radon indoor air**
- **Onsite testing of airwell® for mitigation of radon in well water**
- **Development of a potential proficiency test for radon in water**

Mapping of Radon in Indoor Air and Well Water in Georgia

GEORGIA - EPA Map of Radon Zones

http://www.epa.gov/radon/zonemap.html



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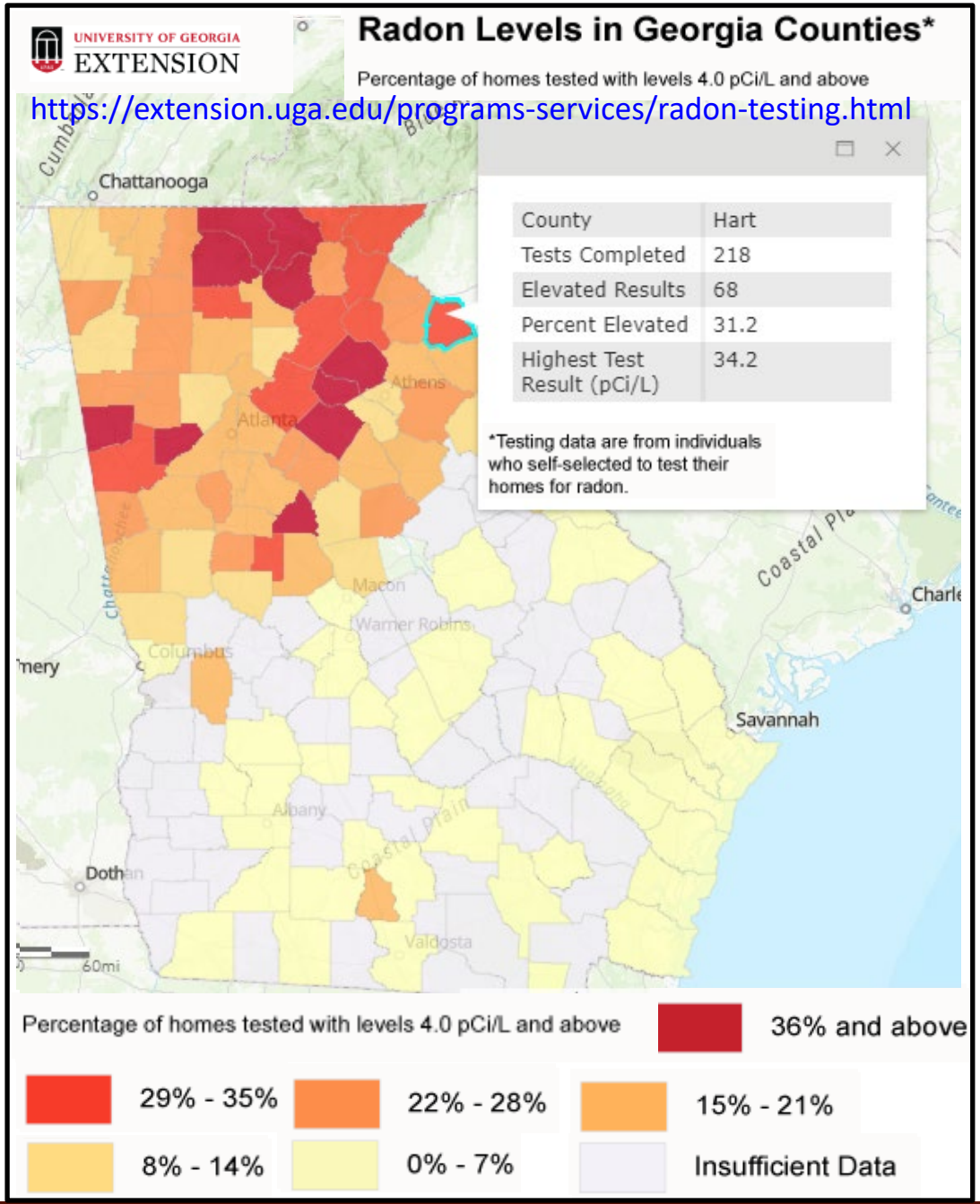
Radon Levels in Georgia Counties*

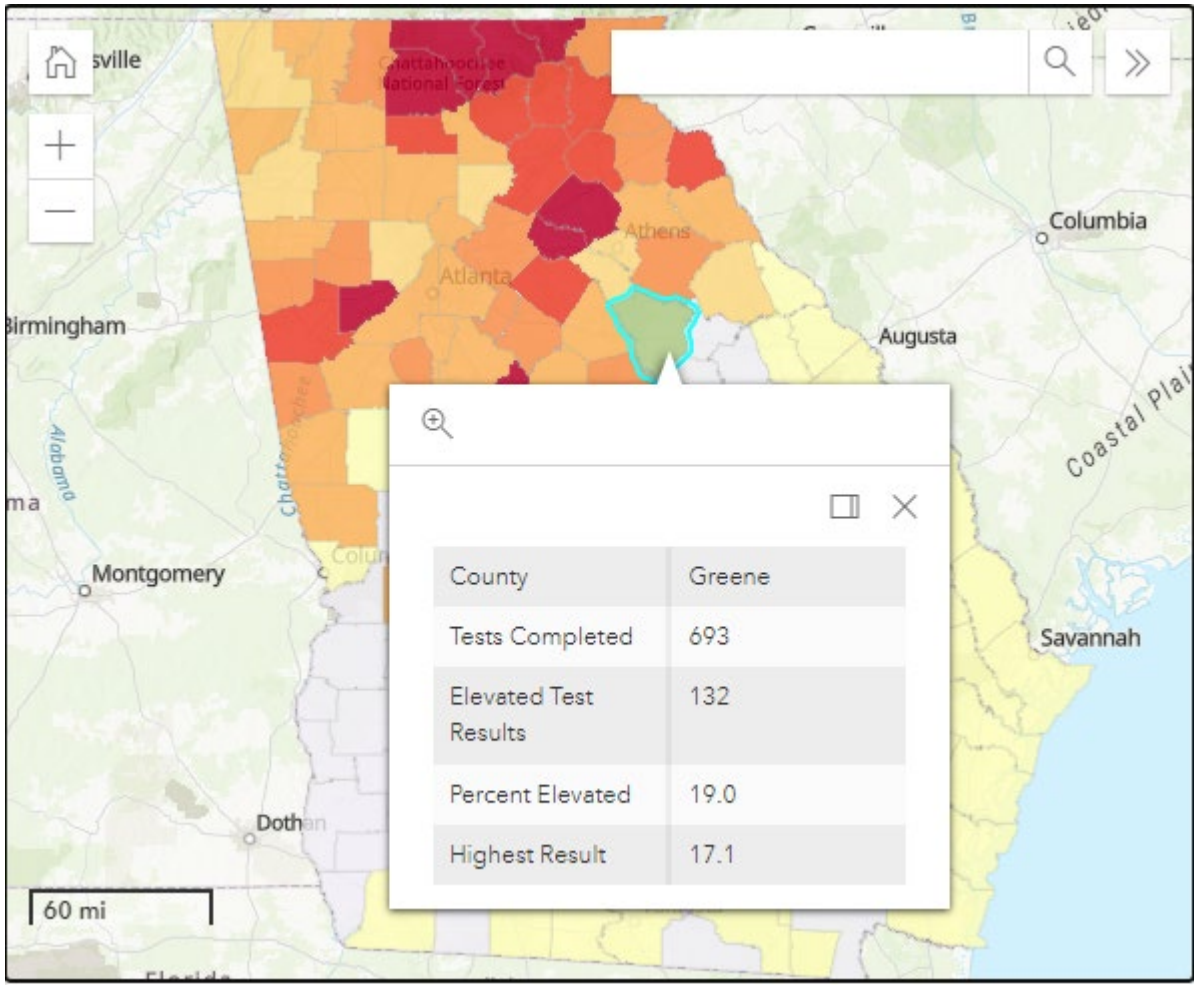
Percentage of homes tested with levels 4.0 pCi/L and above

https://extension.uga.edu/programs-services/radon-testing.html



Georgia radon map updated with data through 2022

- Map summarizes results of 120,000+ tests from 1990 through 2022
- Data set is imperfect; self selected testing and limited to information provided by labs
- Summarized in an interactive map on state program website



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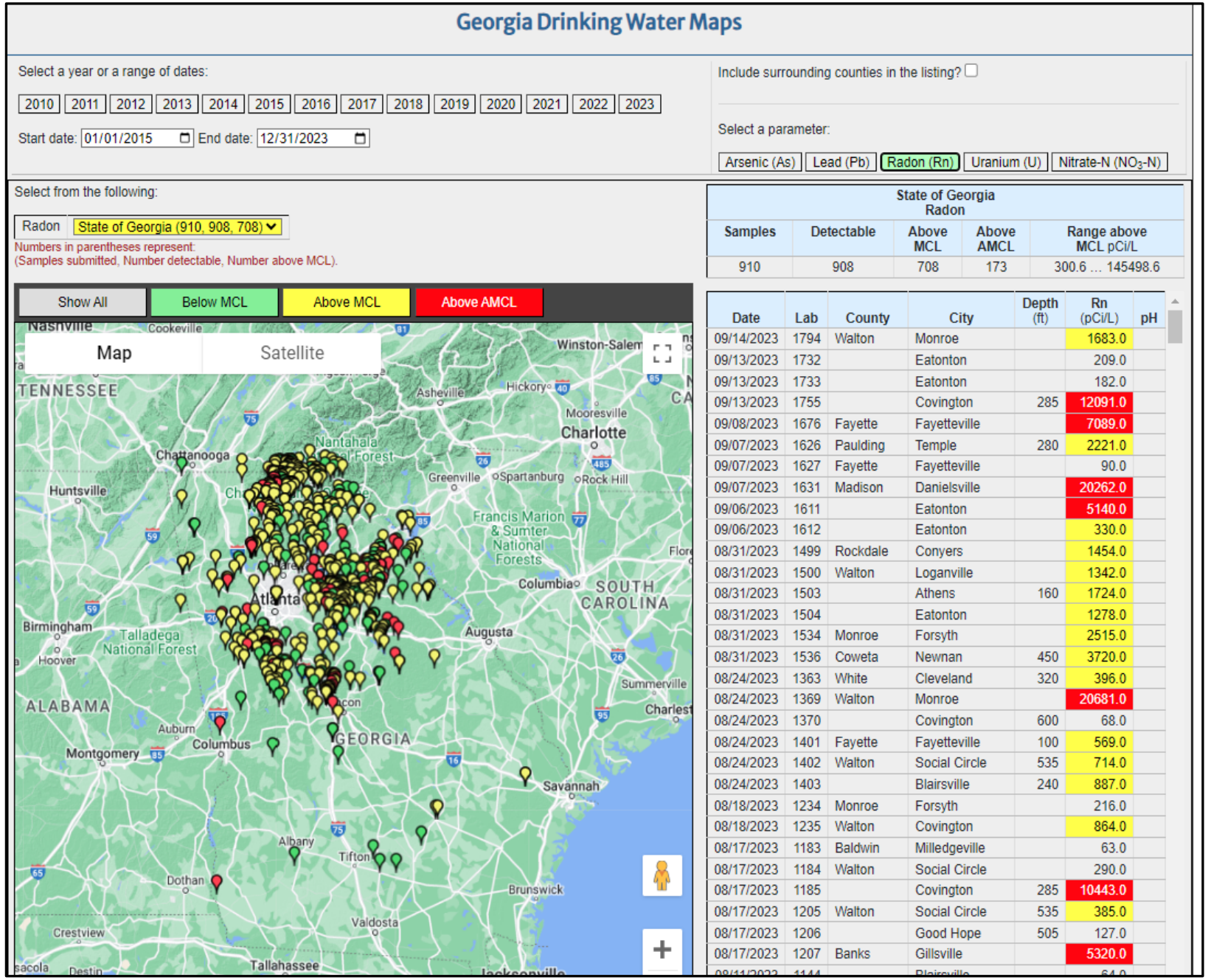
Agricultural and Environmental Services Laboratories

Mapping Radon in Well Water

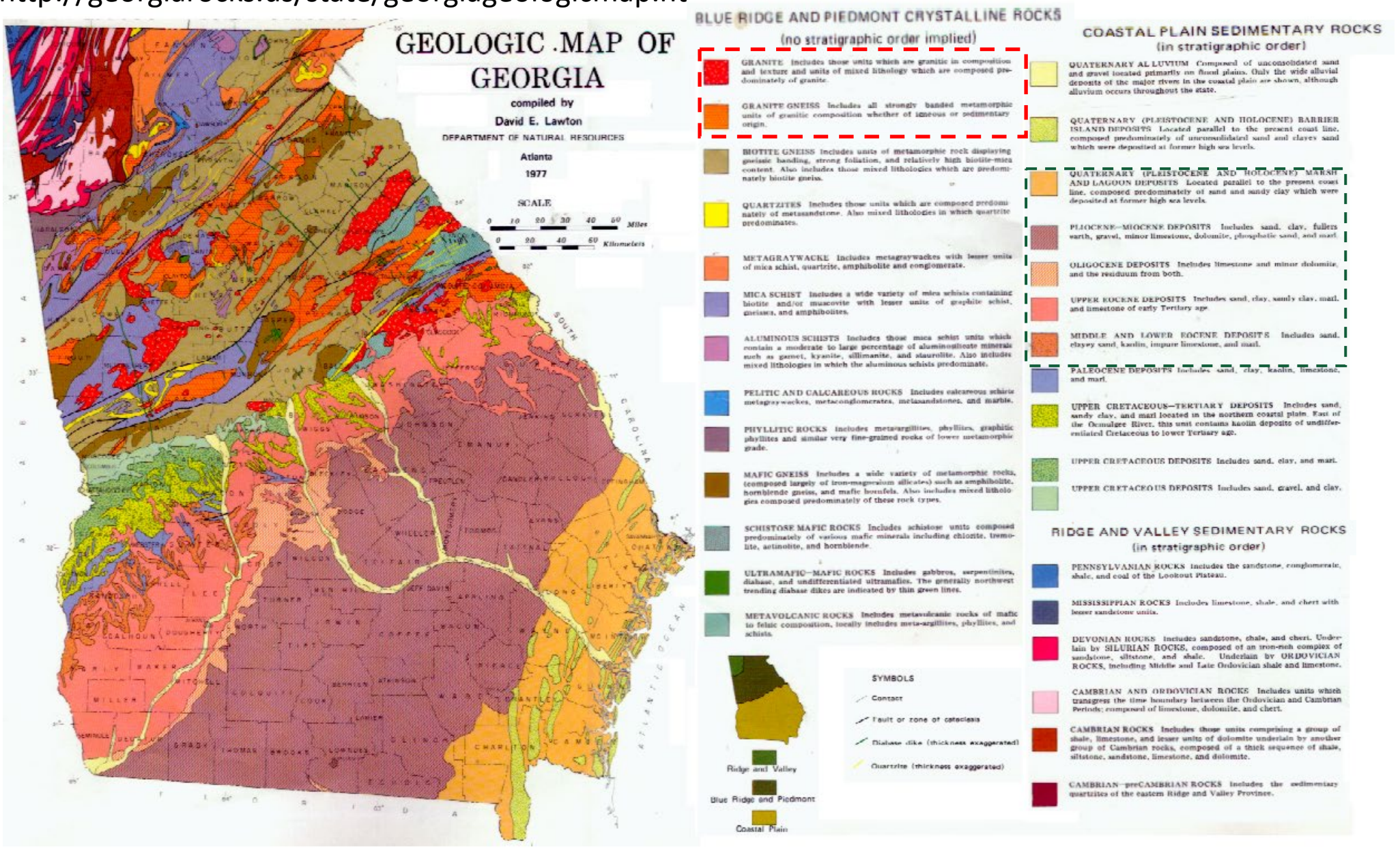
https://aesl.ces.uga.edu/water/map/



Date	Lab	County	City	Depth (ft)	Rn (pCi/L)	pH
09/14/2023	1794	Walton	Monroe		1683.0	
09/13/2023	1732		Eatonton		209.0	
09/13/2023	1733		Eatonton		182.0	
09/13/2023	1755		Covington	285	12091.0	
09/08/2023	1676	Fayette	Fayetteville		7089.0	
09/07/2023	1626	Paulding	Temple	280	2221.0	
09/07/2023	1627	Fayette	Fayetteville		90.0	
09/07/2023	1631	Madison	Danielsville		20262.0	
09/06/2023	1611		Eatonton		5140.0	
09/06/2023	1612		Eatonton		330.0	
08/31/2023	1499	Rockdale	Conyers		1454.0	
08/31/2023	1500	Walton	Loganville		1342.0	
08/31/2023	1503		Athens	160	1724.0	
08/31/2023	1504		Eatonton		1278.0	
08/31/2023	1534	Monroe	Forsyth		2515.0	
08/31/2023	1536	Coweta	Newnan	450	3720.0	
08/24/2023	1363	White	Cleveland	320	396.0	
08/24/2023	1369	Walton	Monroe		20681.0	
08/24/2023	1370		Covington	600	68.0	
08/24/2023	1401	Fayette	Fayetteville	100	569.0	
08/24/2023	1402	Walton	Social Circle	535	714.0	
08/24/2023	1403		Blairsville	240	887.0	
08/18/2023	1234	Monroe	Forsyth		216.0	
08/18/2023	1235	Walton	Covington		864.0	
08/17/2023	1183	Baldwin	Milledgeville		63.0	
08/17/2023	1184	Walton	Social Circle		290.0	
08/17/2023	1185		Covington	285	10443.0	
08/17/2023	1205	Walton	Social Circle	535	385.0	
08/17/2023	1206		Good Hope	505	127.0	
08/17/2023	1207	Banks	Gillsville		5320.0	

Bivariate Associations Between the Physiographic Provinces and the Proportion of Indoor Air Radon Concentration At or Above 4.0 pCi/L

http://georgiarocks.us/state/georgiageologicmap.html

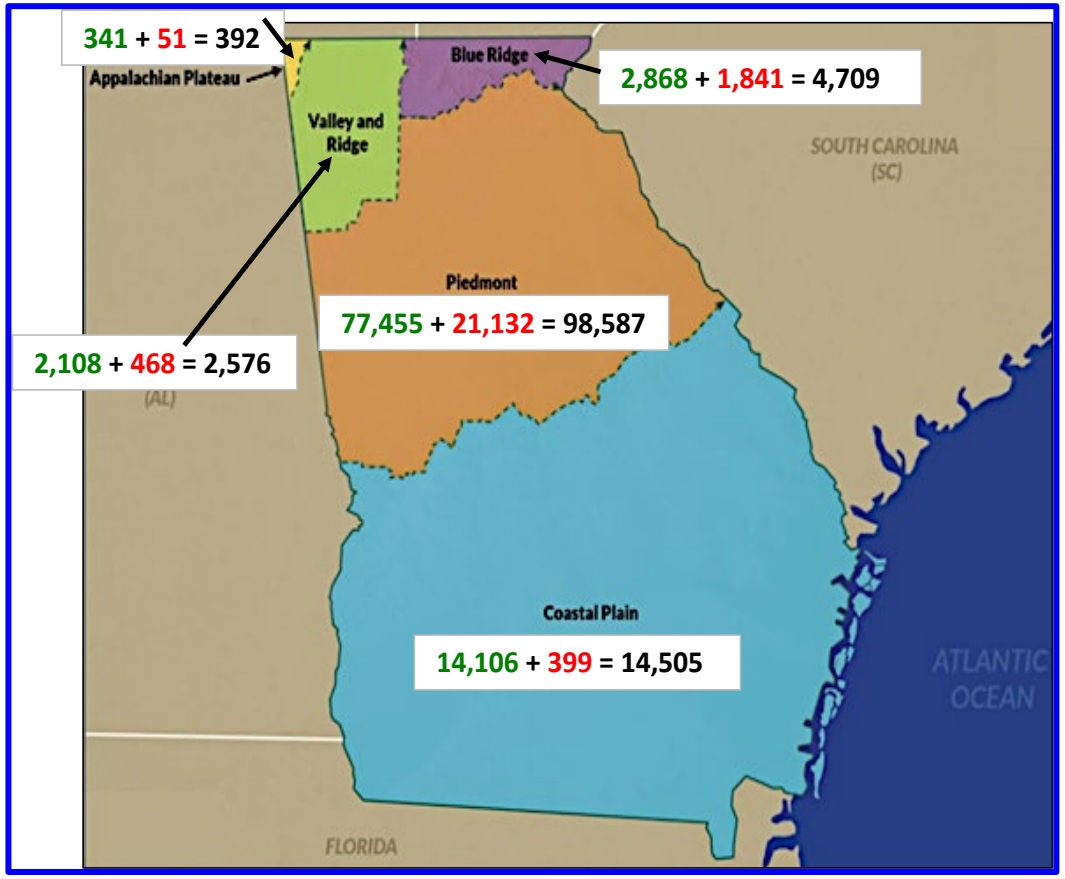


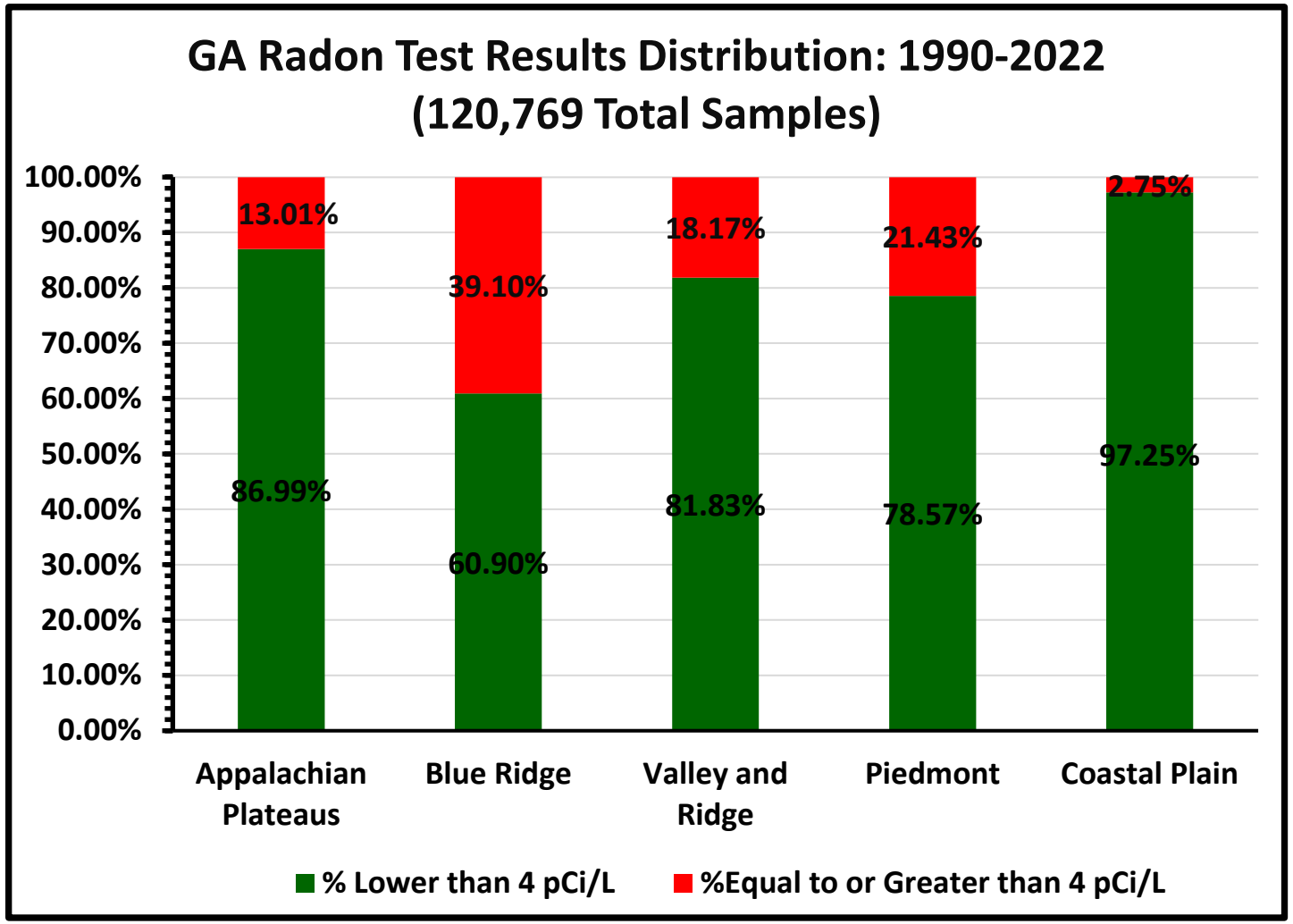
Chi-Square Test: Association of the Distribution with the Physiographic Provinces

χ^2 (df = 4, N = 120,769) = **3,943.5**, p < **0.00001**

GA Radon Test Results: 1990-2022
Total: 120,769

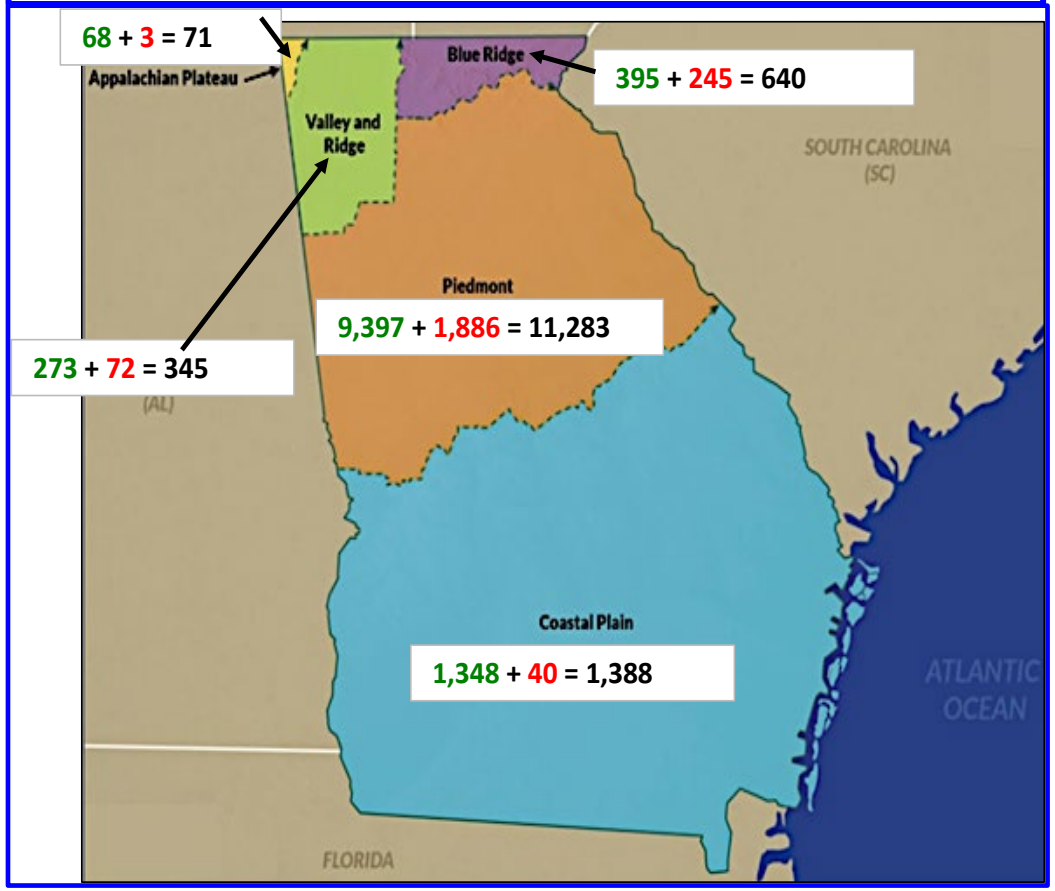
- Green: Number of Test results Lower than 4 pCi/L
- Red; Number of Test results Equal or Greater than 4 pCi/L
- Black: Total Tests





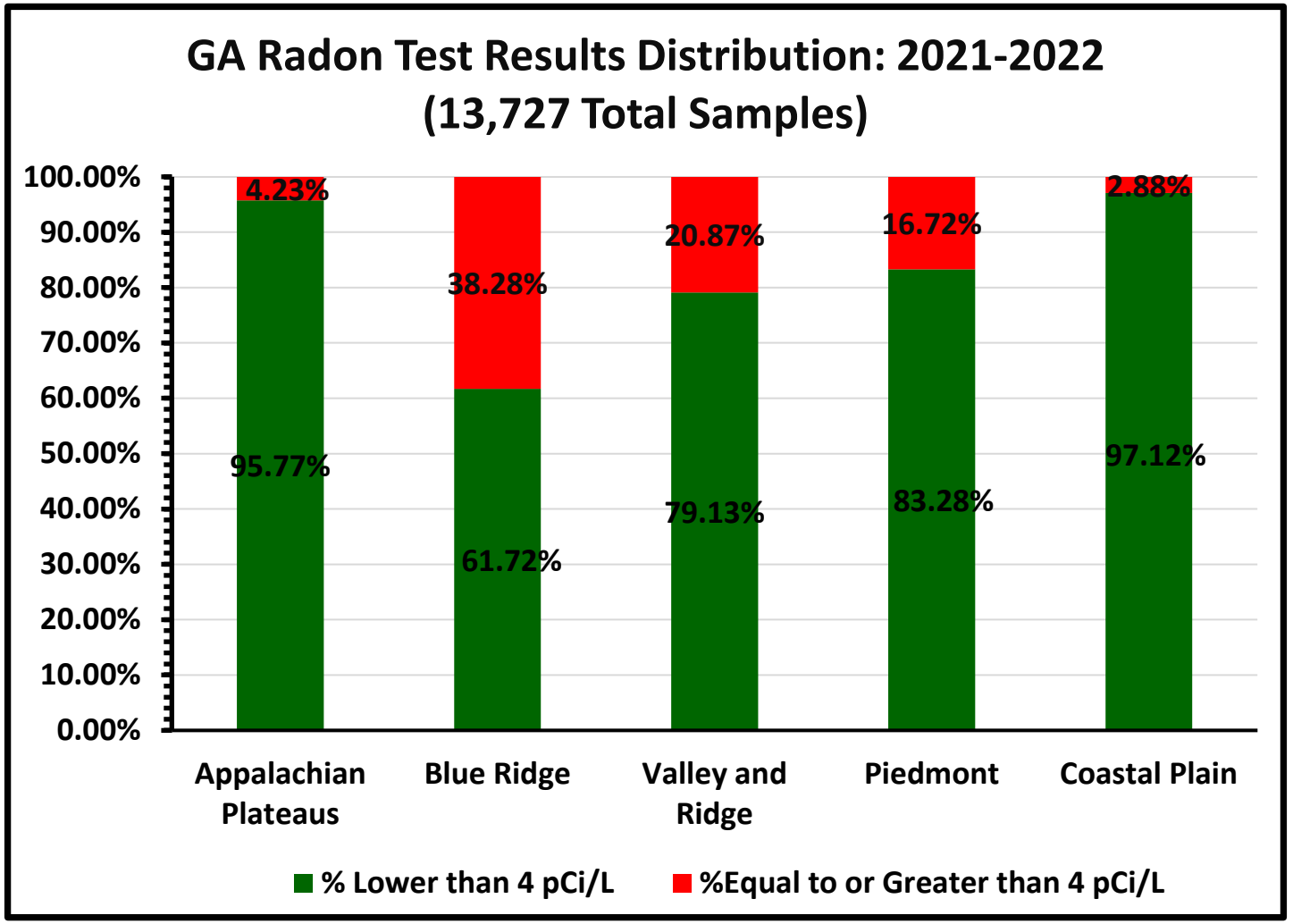
GA Radon Test Results: 2021-2022
Total: 13,727

- Green: Number of Test results Lower than 4 pCi/L
- Red; Number of Test results Equal or Greater than 4 pCi/L
- Black: Total Tests



Chi-Square Test: Association of the Distribution with the Physiographic Provinces

χ^2 (df = 4, N = 13,727) = **422.79**, p < 0.00001



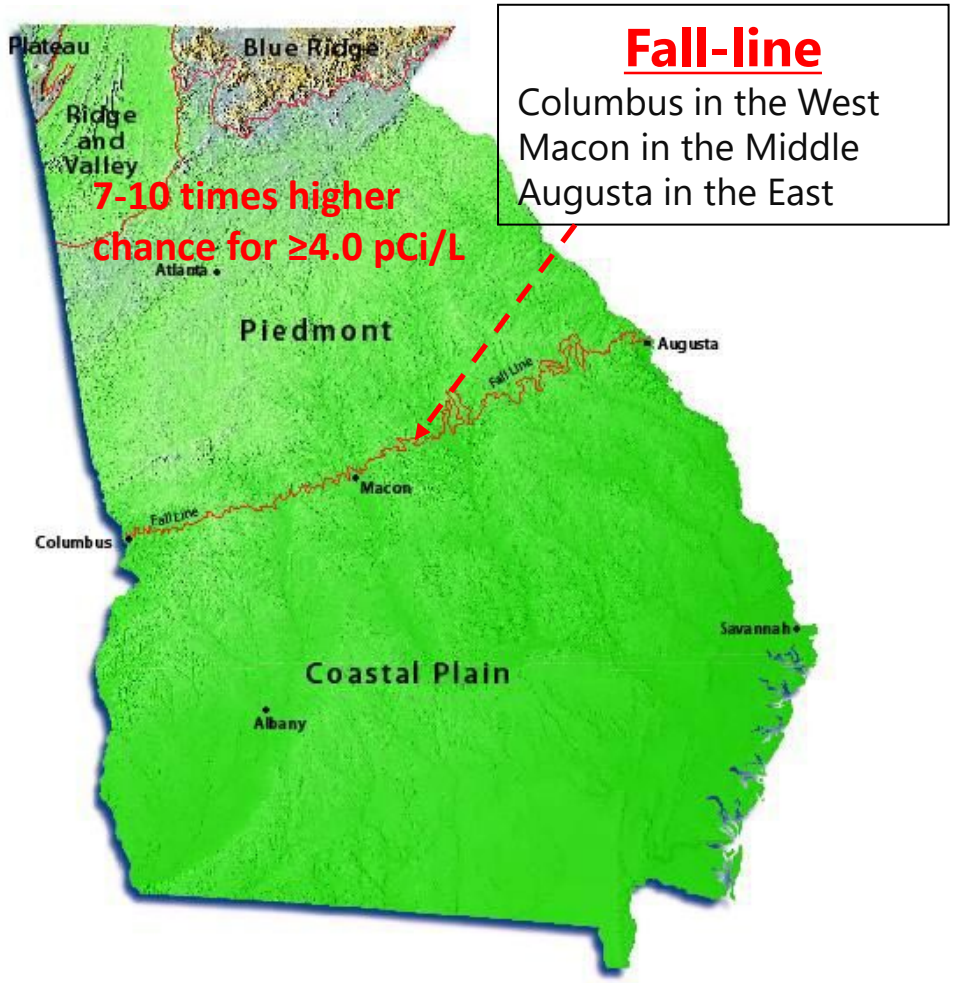
ODDS Ratio

GA Radon Test Results: 1990-2022 (Total: 120,769)

Zone	Equal to or Greater than 4 pCi/L	Lower than 4 pCi/L
Above Fall Line	23,492 [A]	82,772 [B]
Below Fall Line	399 [C]	14,106 [D]
ODDS Ratio = (A x D)/(B x C) = (23,492 x 14,106)/(82,772 x 399) = **10.03**		

GA Radon Test Results: 2021-2022 (Total: 13,727)

Zone	Equal to or Greater than 4 pCi/L	Lower than 4 pCi/L
Above Fall Line	2,206 [A]	10,133 [B]
Below Fall Line	40 [C]	1,348 [D]
ODDS Ratio = (A x D)/(B x C) = (2,206 x 1,348)/(10,133 x 40) = 7.34		



The chances of getting equal to or greater than 4.0 pCi/L test results are <u>7-10 times higher in the area above the fall-line</u> than below the fall-line.

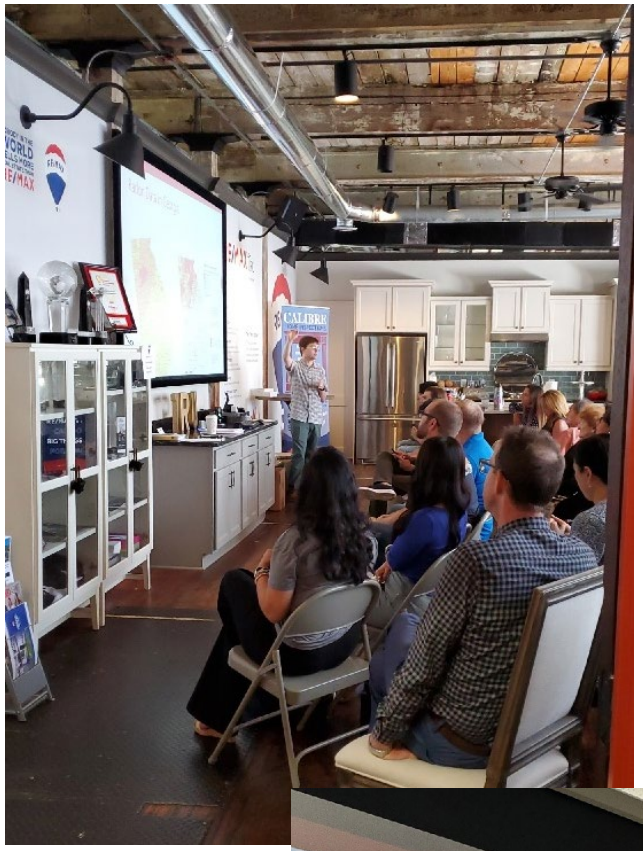
New Initiatives to Increase Testing, Public Awareness, and Mitigation of Radon Indoor Air

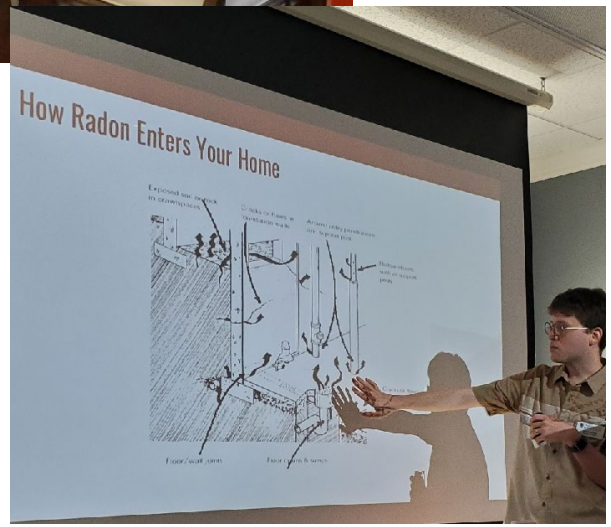
- **Library Loan Program**
- **Real Estate Agents CE Courses**
- **Promotion Through 4H Youth Education**

Library Radon Monitor Check out Program

- Partnership between GPLS and UGA Extension Radon Education Program
- 400+ monitors provided by UGA Extension
- Electronic monitors made available to public for checkout by GPLS

GEORGIA PUBLIC LIBRARY SERVICE + RADON EDUCATION = A safer, healthier Georgia

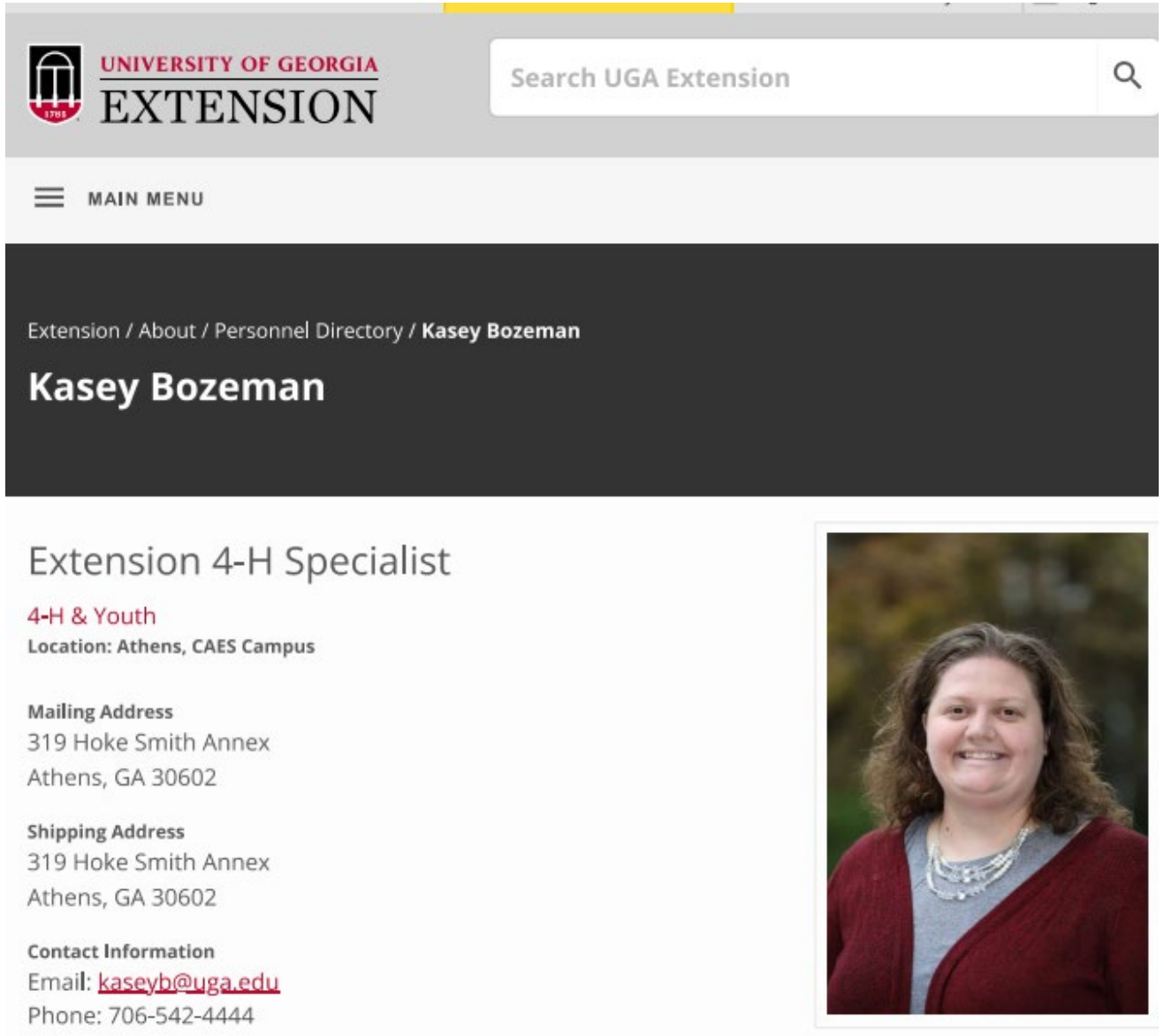




Radon Real Estate School

- Program became an approved real estate school in 2022
- GA Real Estate agents require 8 hours of CE annually
- Program has provided 315 credit hours of training to real estate agents in the last year focused solely on radon

Promotion Through 4-H Youth Education



Inclusion of Radon in the UGA's 4-H Youth Education

- 4-H'ers are great channels for conveying educational information to the parents and community.
- UGA 4-H agents/educators go to the schools and have a 30-minute educational session with 4th-6th graders once a month.
- Curriculum development with a UGA 4-H specialist is in progress.
- Expecting to launch the program in the NRAM 2024.

Onsite Testing Demonstration of Airwell® for Mitigation of Radon in Well Water

BACKGROUND

- **In Georgia, an increasing number of private wells are showing radon concentration exceeding EPA's suggested AMCL of 4,000 pCi/L, which require mitigation to a safe level.**
- **Radon level higher than 100,000 pCi/L is also not uncommon in Georgia private wells.**
- **Mitigation of radon in water is fairly new relative to soil gas reduction in homes.**
- **A point-of-entry 'Aeration' or 'Granular Activated Carbon' treatment system is commonly used.**

BACKGROUND

- **However, mitigation of radon higher than 100,000 pCi/L water has not been well documented by any methods.**
- **Airwell™ technology has claimed to be able mitigate any high level of radon in water.**
- **Thus, the technology could potentially be used in Georgia homes with very high level of radon in water, e.g., >100,000 pCi/L.**
- **However, such claim seemed to lack enough supportive evidence from real-life situations.**
- **Therefore, we felt the necessity to test the application of Airwell™ technology on-site, in collaboration with the company.**

BACKGROUND

- **No doubt, the outcomes of the on-site Mitigation Demonstration Projects are going to benefit both UGA Radon Program and the company. For example,**

  - ✓ **Give us confidence on making radon in water mitigation.**
  - ✓ **Valuable real-life mitigation performance data and a rewarding experience vital to the company for situation-specific fine tuning of the Airwell™ technology.**
  - ✓ **That means a Win-Win for both.**

BACKGROUND

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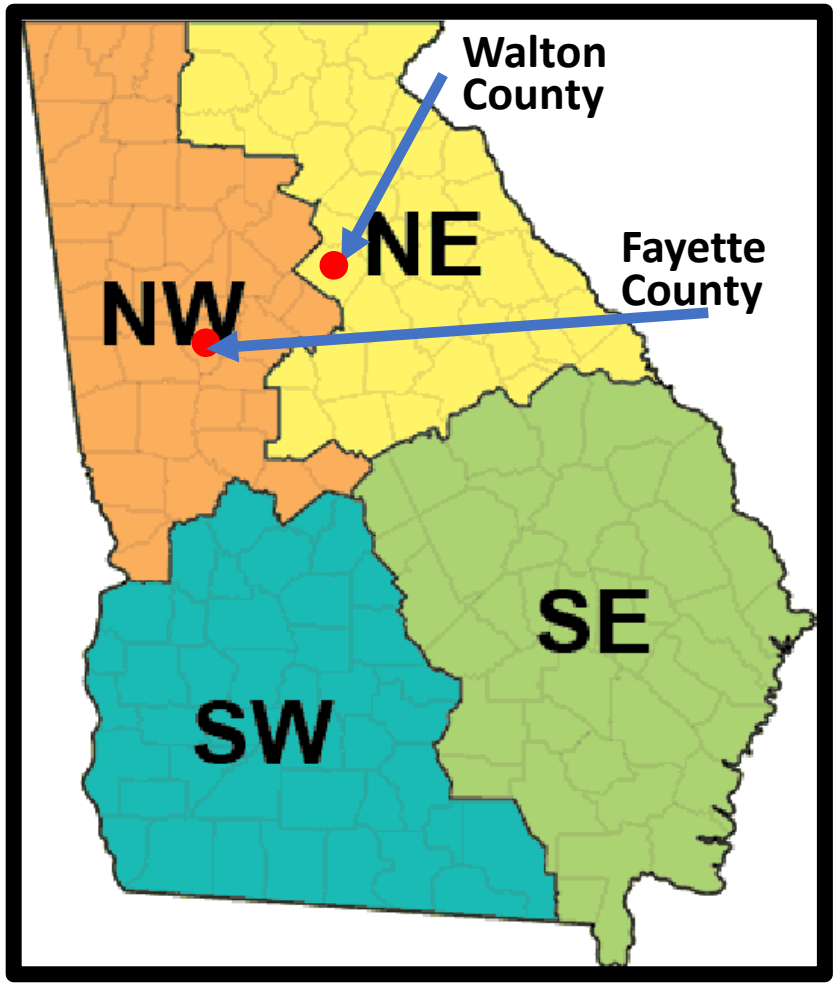
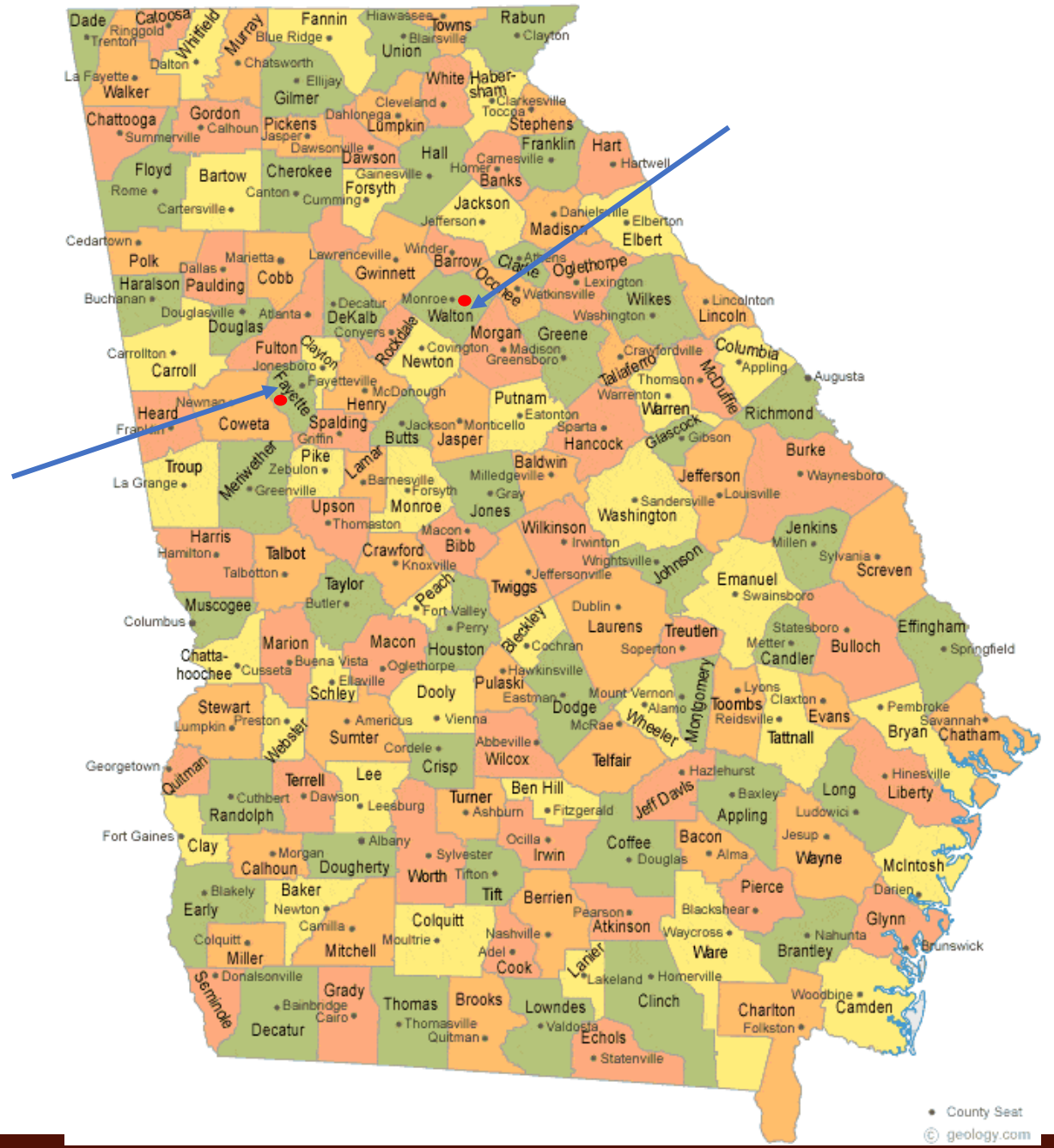
DISTRICTS AND COUNTIES





State of Georgia Radon in Well Water Since 2015
At University of Georgia Water Laboratory
(As of 9-15-2023)

Number of Wells Tested	Detectable (>100 pCi/L)	Above MCL (>300 pCi/L)	Above AMCL (>4000 pCi/L)	Range above MCL pCi/L
State-wide				
910	**908**	**708**	**173 (19%)**	**300.6 to 145,498**
Walton County				
127	127	94	**42 (33%)**	300.6 to **145,498**
Fayette County				
14	14	10	**5 (36%)**	300.6 to **55,311**

Airwell™ – Removes Radon from Water

Radon Environmental: https://radoncorp.com/
https://www.youtube.com/watch?v=miD5te02_CE
https://www.youtube.com/watch?v=ga_Zcd6tZcc



- **A fairly new technology removes radon from well water before water enters the home.**
- **Uses a "down the well" process by injecting air into the water source through an aeration pipe.**
- **Using pressurized air pumped to the bottom of the well, contaminated water is lifted to the surface.**
- **Radon, Hydrogen sulfide, methane, and carbon dioxide are released.**
- **Oxidizes iron and manganese and form particles.**
- **Thus, the system quickly and reliably removes several contaminants.**
- **An automatic and maintenance free (?) system with minimal operating cost, uses no chemicals.**

THE DEMONSTRATION PROJECTS

- **In collaboration with the company and necessary funding from USEPA through a Multipurpose Grant (MPG), we installed onsite demonstrations of radon mitigation using Airwell™ in 3 private wells:**

Site Identification	Radon Concentration
Well-1 (Walton County)	9,302 pCi/L
Well-2 (Walton County)	145,498 pCi/L
Well-3 (Fayette County)	55,311 pCi/L

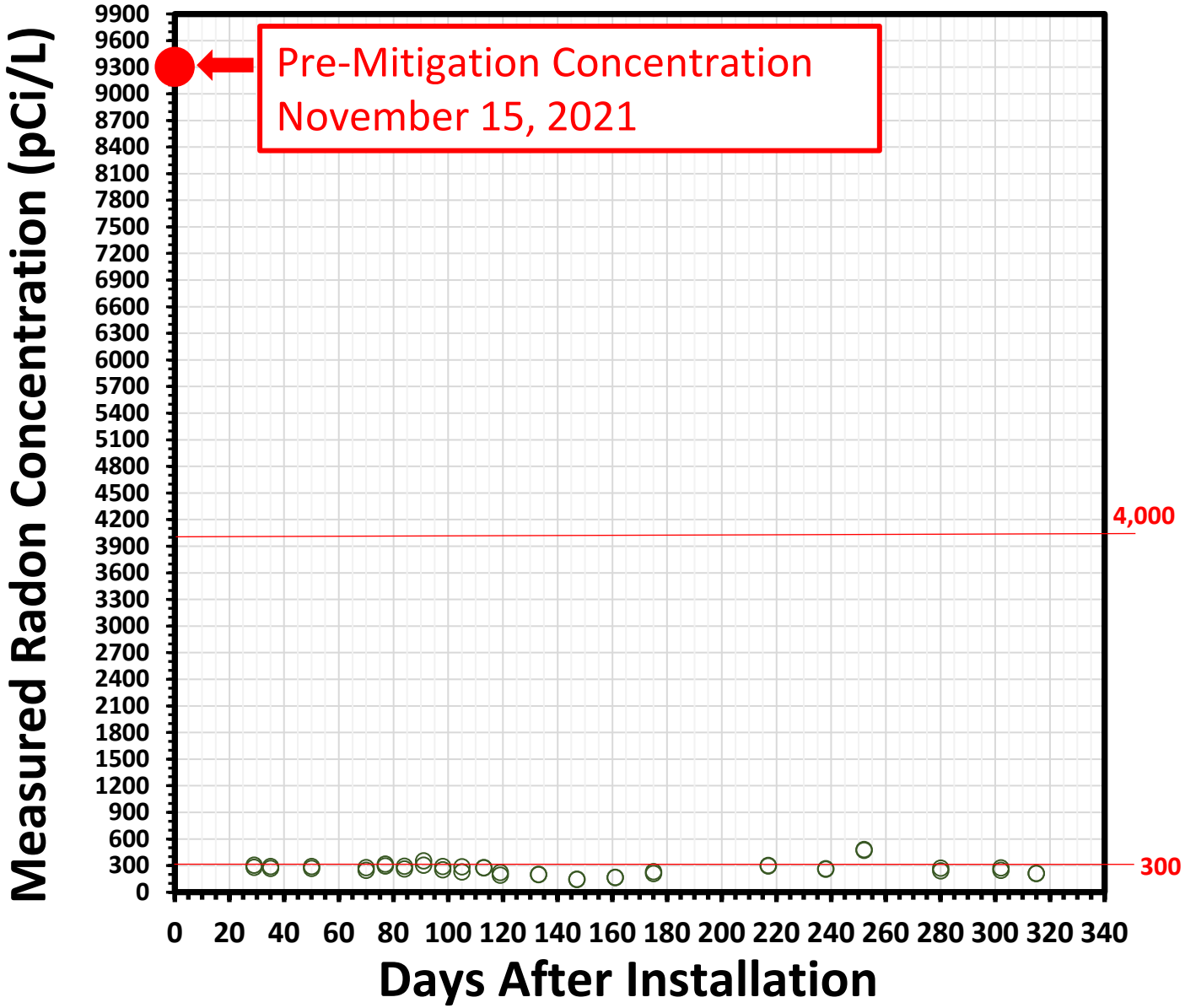
- **Post-mitigation radon concentrations in these 3 wells are being monitored weekly or bi-weekly.**
- **Monitoring will continue for at least two years at various intervals to evaluate the long-term mitigation performance**

THE DEMONSTRATION PROJECTS

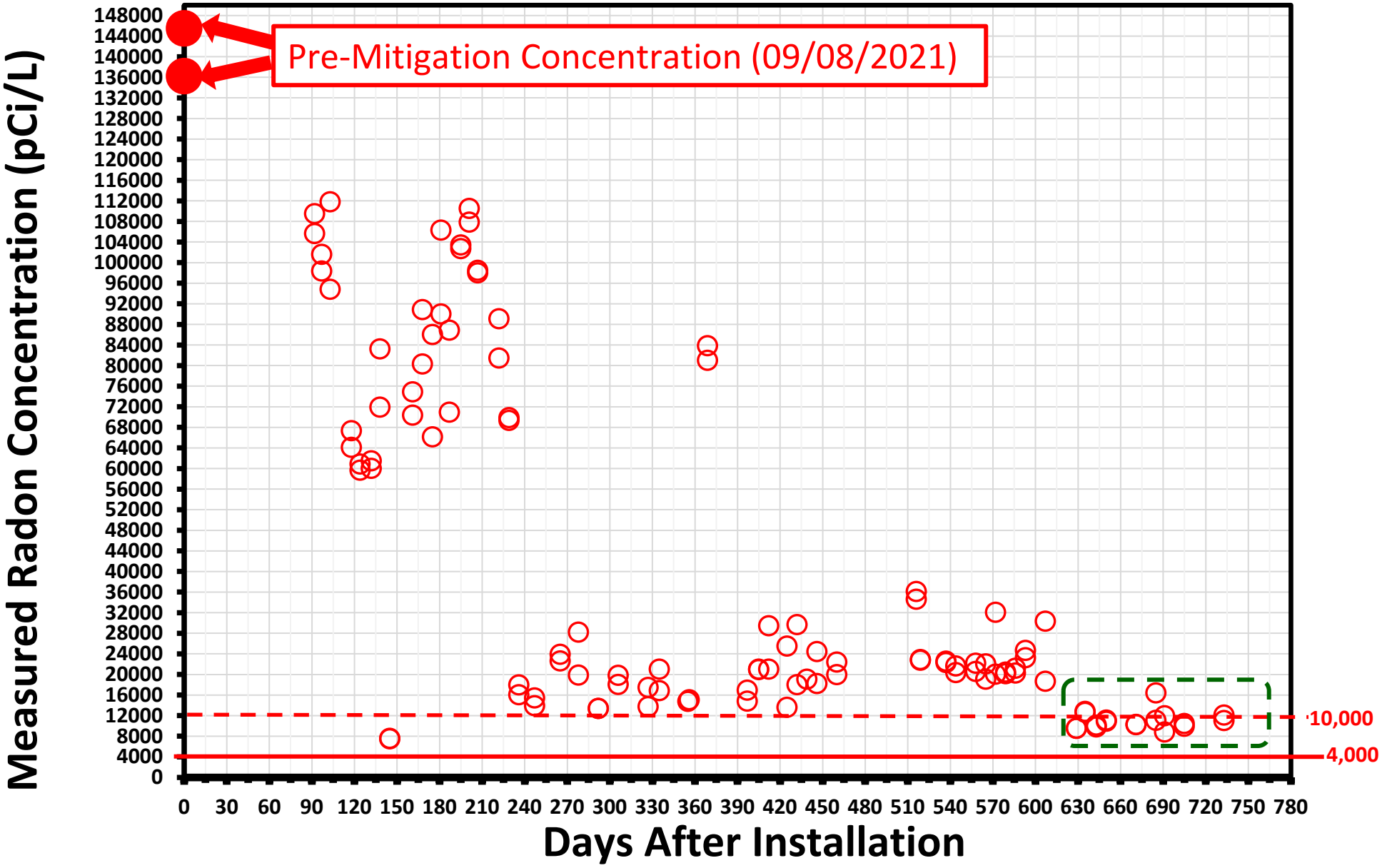
- **Maintenance needed, problem encountered, troubleshooting, corrective actions, and other issues are being recorded.**

- **We are presenting an up-to-date results of these 3 demonstration projects.**

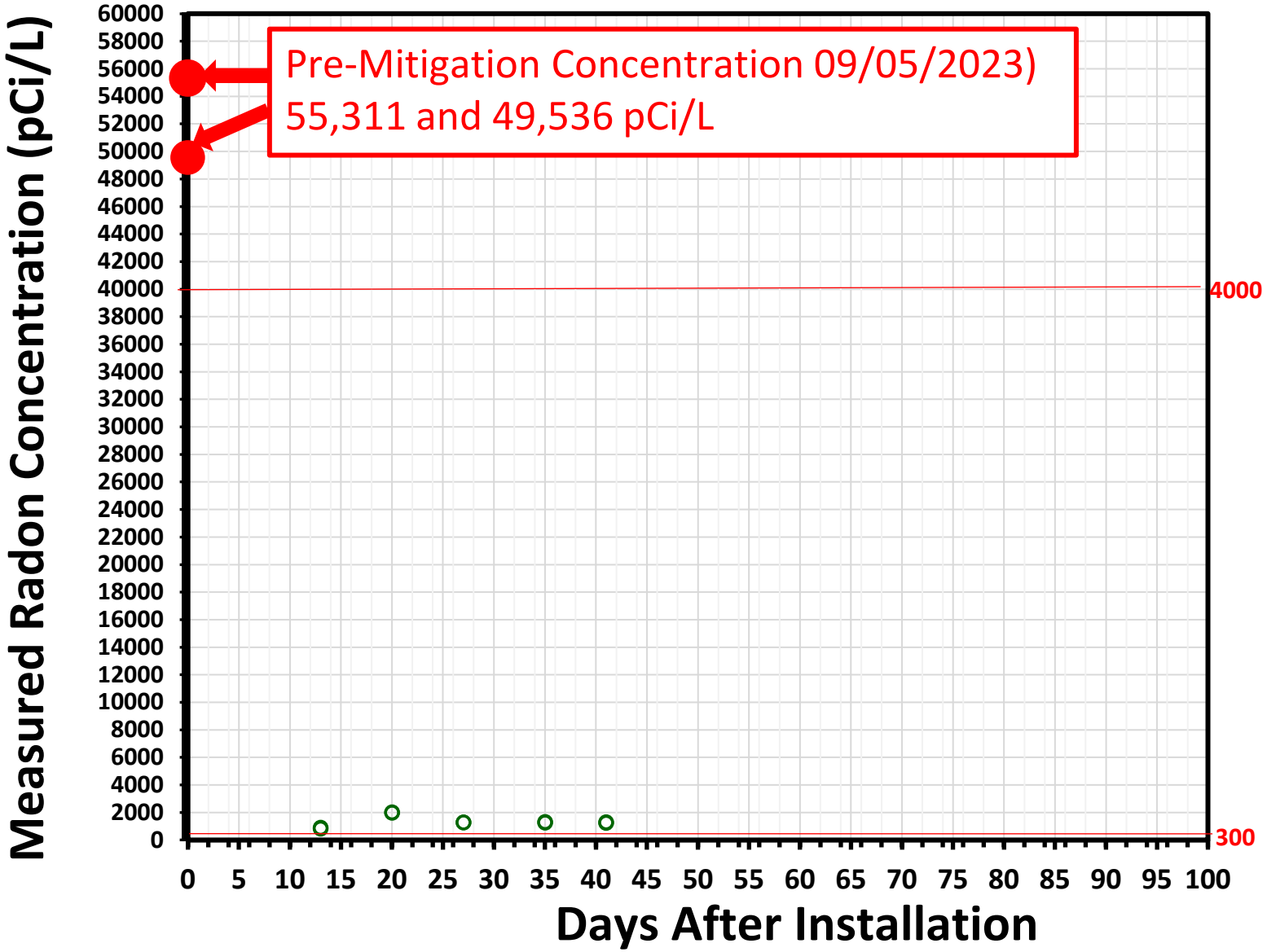
Well-1: Walton County



Well-2: Walton County

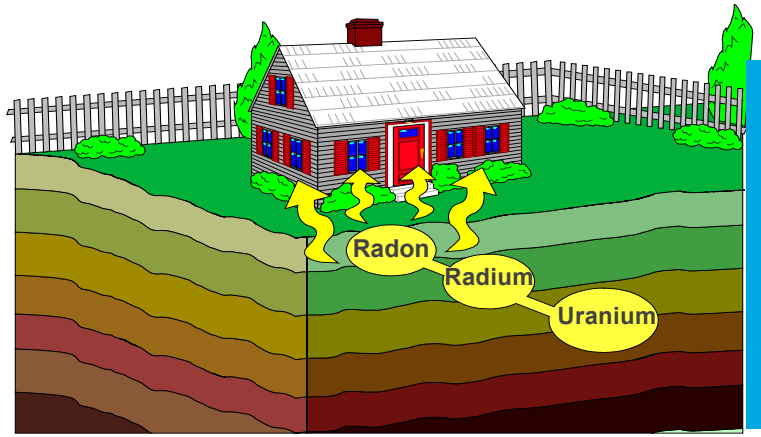


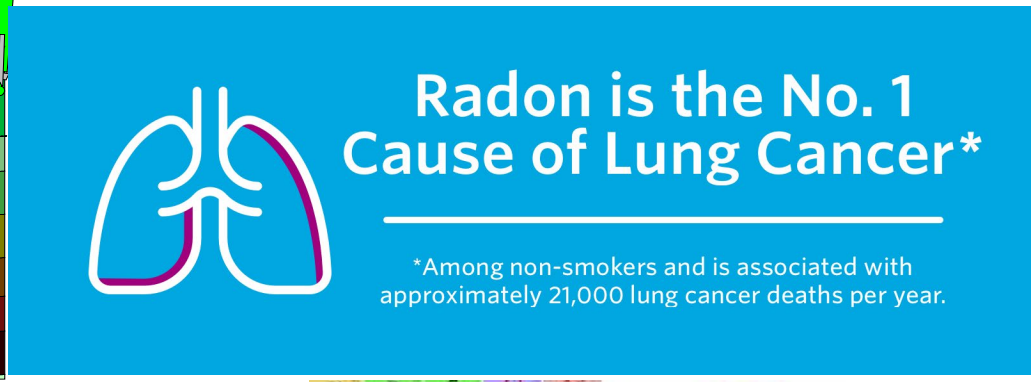
Well-3: Fayette County



Developing a Proficiency Test for Radon in Water

– with a worldwide potential!





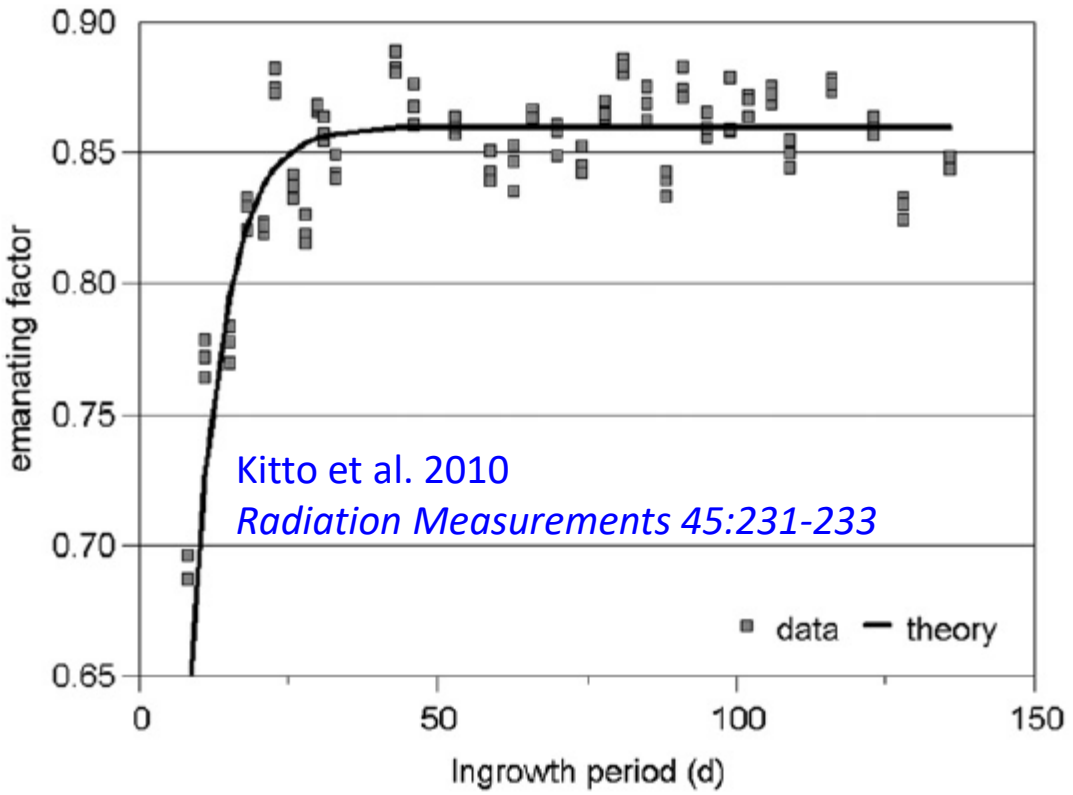
- **Proficiency Test (PT)** – *an integral part of Quality Assurance in Analytical Chemistry*.

- **We do not have one** for Radon-in-Water.

- How about **accreditation** in analyzing radon in water?

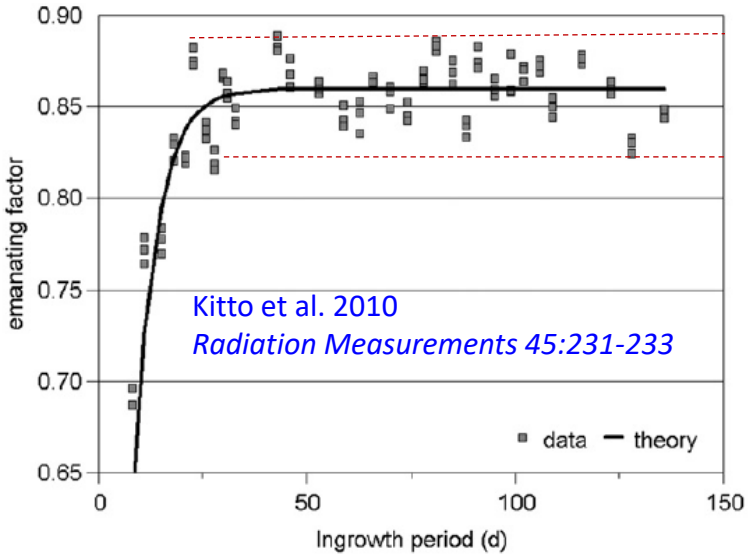
Reusable Proficiency Test (PT) Samples

- Two ^{222}Rn-in-water "proficiency test" samples from NYDOH.
- Reusable radon-in-water standards prepared using a ^{226}Ra-loaded filter sandwiched in polyethylene sheeting (Kitto et al., 2010).
- At full ingrowth (>30 days), the ^{222}Rn in both should be **4,375 pCi/L** at 100% emanation.
- But due to retardation by the polyethylene, produces only **3,763 pCi/L** at 86% emanation.



Reusable Potential PT Samples

Measured every 40-50 day in-growing over a period of 6 years 2016-2022.



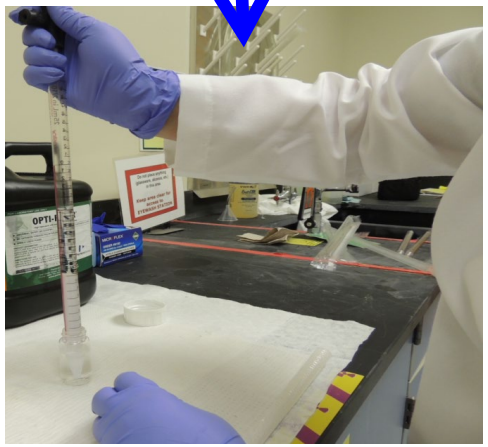
The results of these measurements were evaluated using acceptance window: 139 ± 35 Bq/L or 3763 ± 940 pCi/L (i.e., a ±25% acceptance window) .

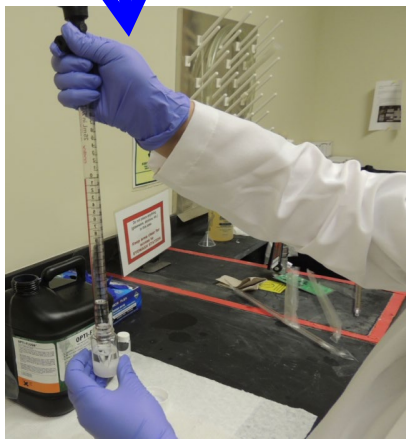
Variables Compared

- **Two Different Scintillation Fluids:**
  - ✓ **Mineral Oil (8 mL + 8 mL Sample)**

  versus
  - ✓ **Opti-Fluor (8mL + 8 mL Sample)**

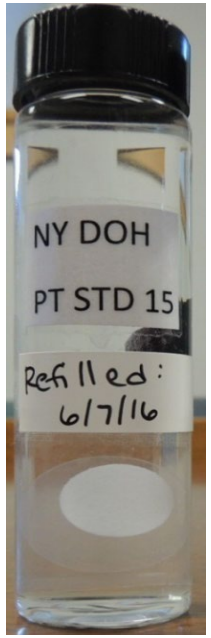
- **Two Sample Preparation Methods:**
  "Simultaneous Drawing " *versus* "Separate Drawing"



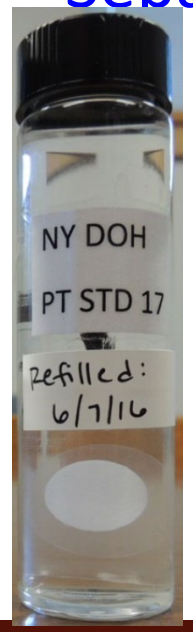


Variables Compared

During Each measurement:



1. **Mineral oil**—Simultaneous drawing
2. **Mineral oil**—Separate drawing
3. **Opti-fluor**—Simultaneous Drawing
4. **Opti-fluor**—Separate drawing



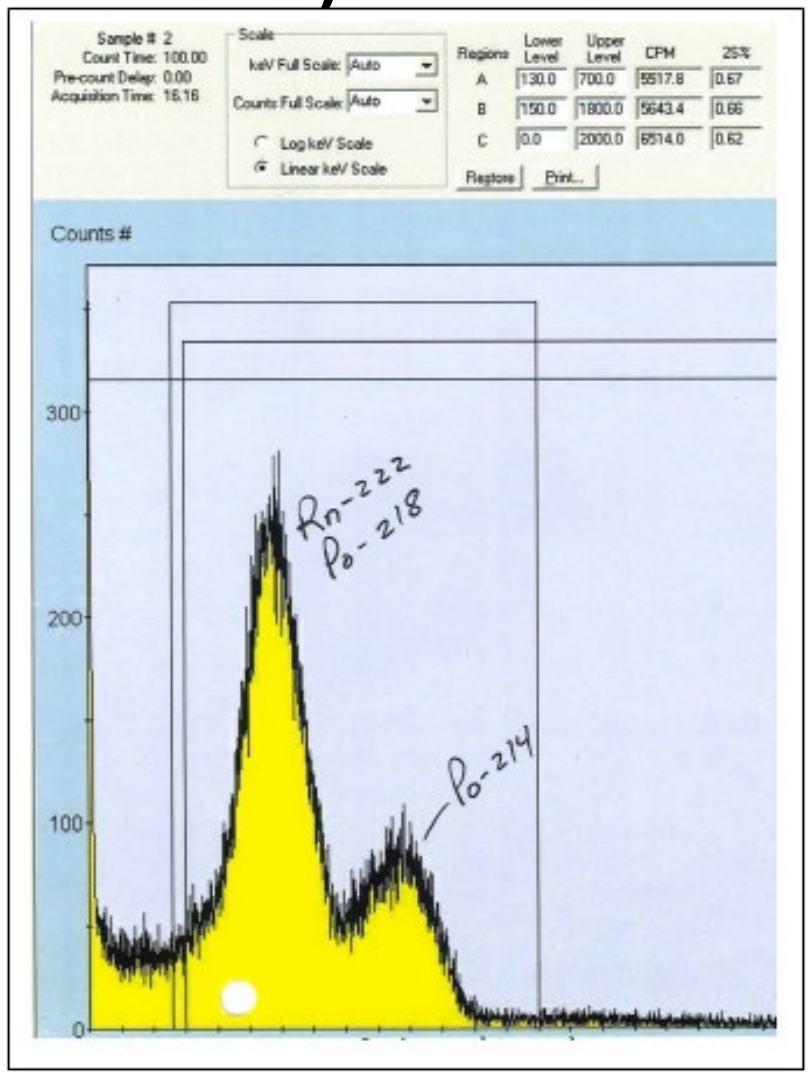
1. **Mineral oil**—Simultaneous drawing
2. **Mineral oil**—Separate drawing
3. **Opti-fluor**—Simultaneous Drawing
4. **Opti-fluor**—Separate drawing

All 8 preparations were analyzed by both 0-2000 keV and 130-700 keV ROI LSC Assays

Variables Compared

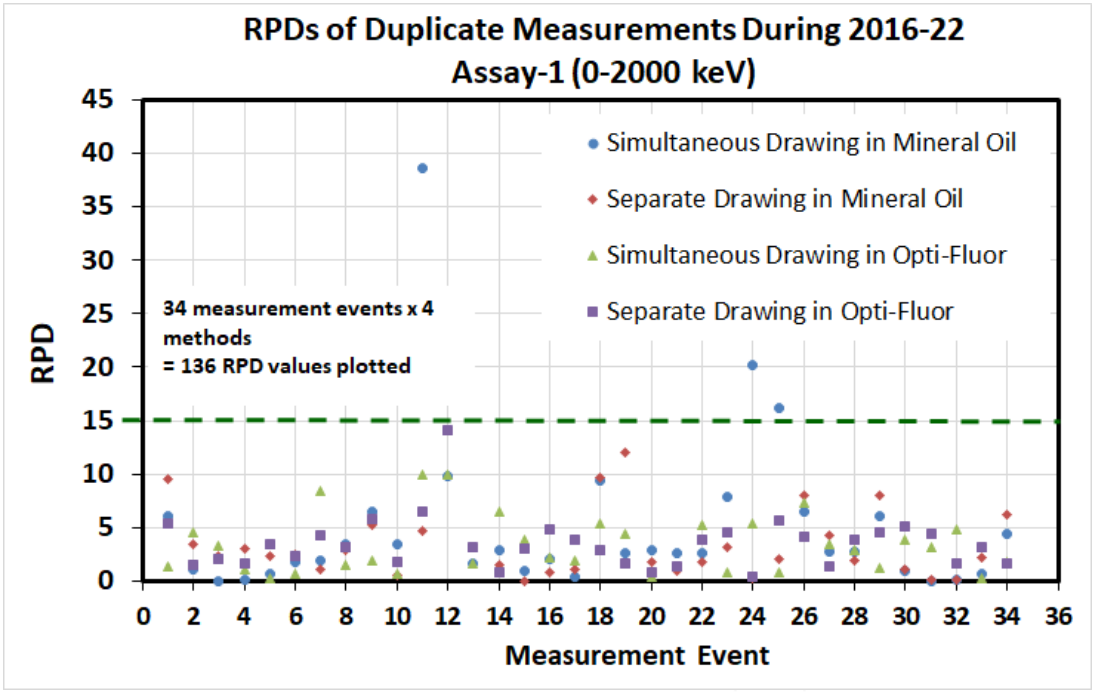
- **Two Different LSC Assays: Full spectrum (0 to 2000 keV) *versus* ROI of ^{222}Rn (130-700 keV)**

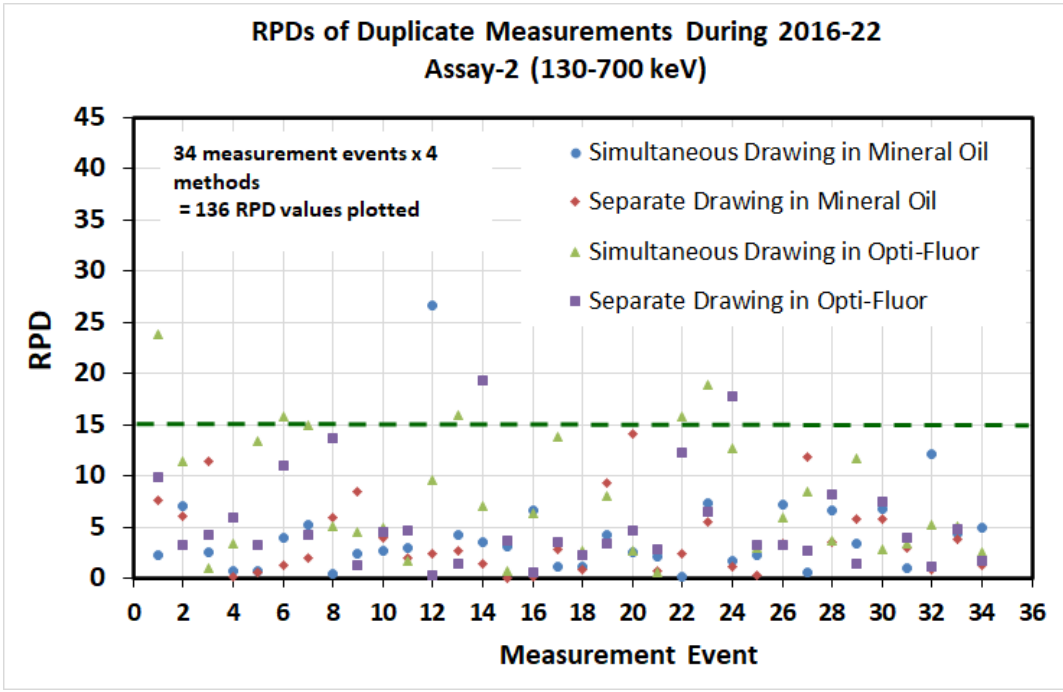
Regions	Assay-1			Assay-2	
	Lower Limit (keV)	Upper Limit (keV)		Lower Limit (keV)	Upper Limit (keV)
A	0	2000		130	700
B	0	2000		150	1800
C	0	2000		0	2000



- **Limited within the ROI for ^{222}Rn from 130 to 700 keV, excluding the counts below 130 keV** (*which is indeed from "Bremsstrahlung" radiation*)**.**
- **Cutting out the low-energy (below 130 keV) betas also reduces the quenching and background.**

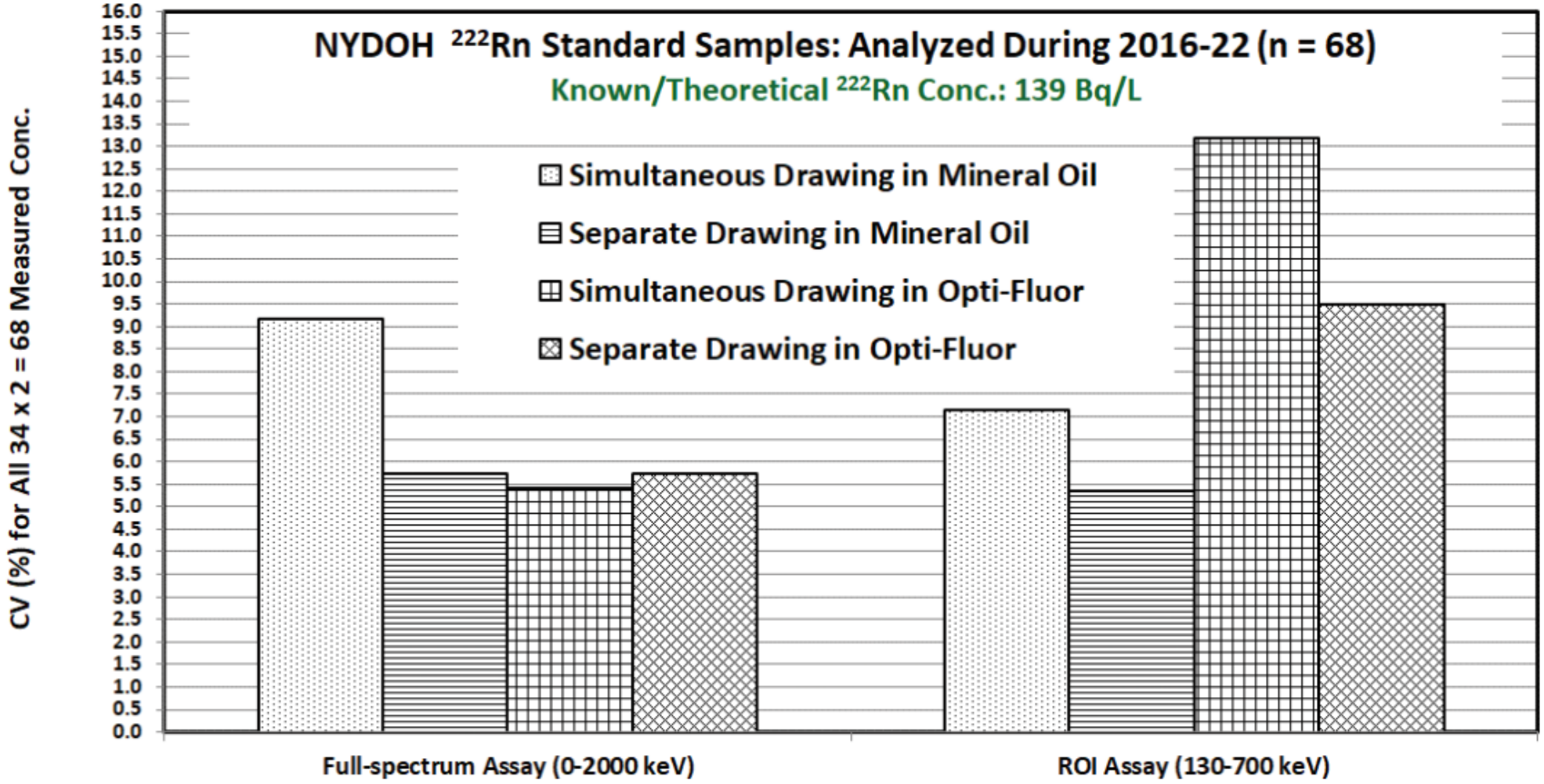
Precision of Duplicate Results



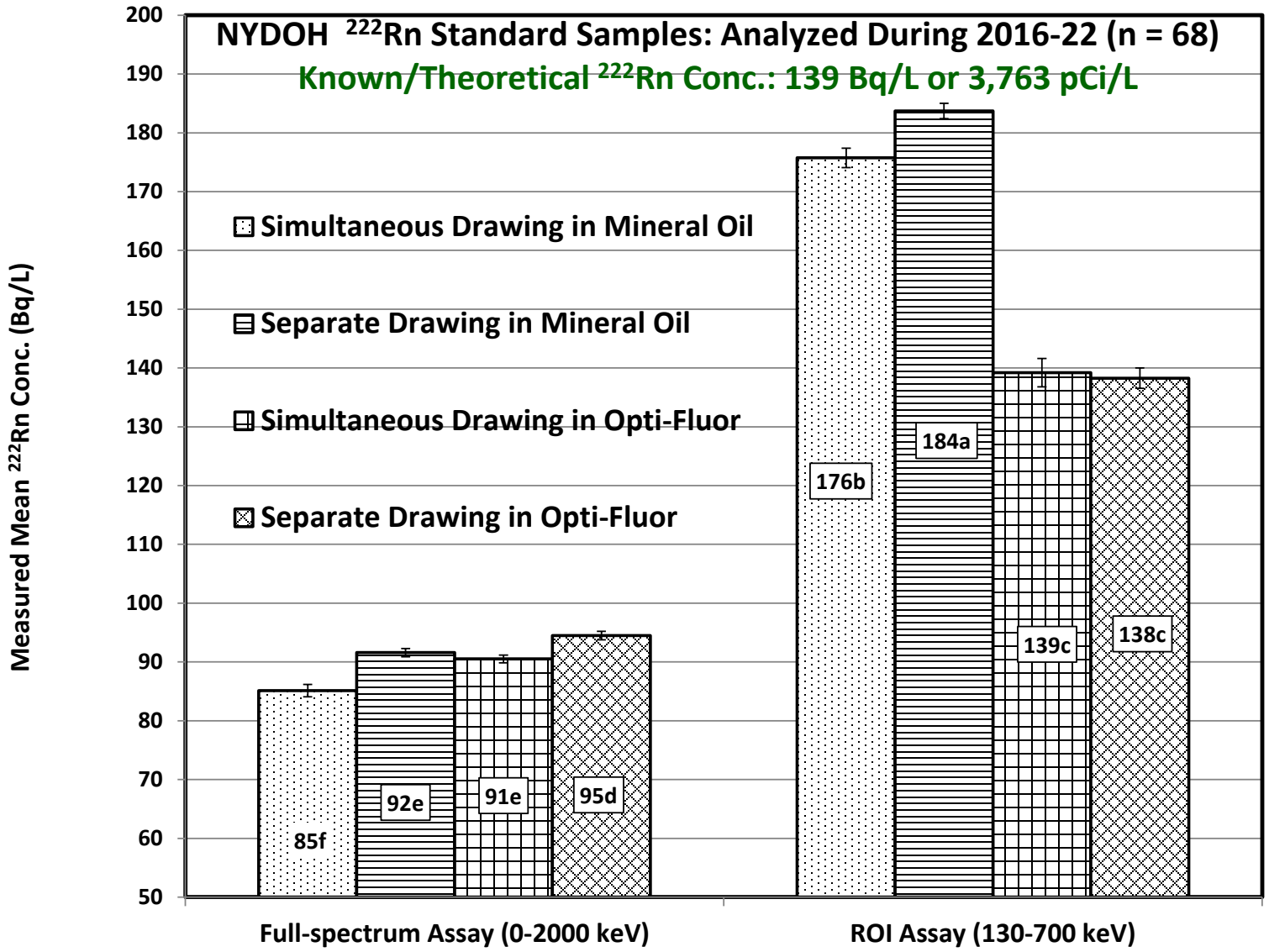


RPD thresholds	Number of RPD values	
	Region of Interest (ROI) assay (130–700 keV)	Full-spectrum assay (0–2,000 keV)
Below 5% (0–4.99%)	86	104
Below 10% (i.e. 0–9.99%)	115	129
Below 15% (i.e. 0–14.99%)	128	132
Above 15% (i.e. 15 and higher)	8	4
TOTAL: Below 15% + Above 15%	128 + 8 =136	132 + 4 =136

Precision of Duplicate Results: Coefficient of Variation (CV)



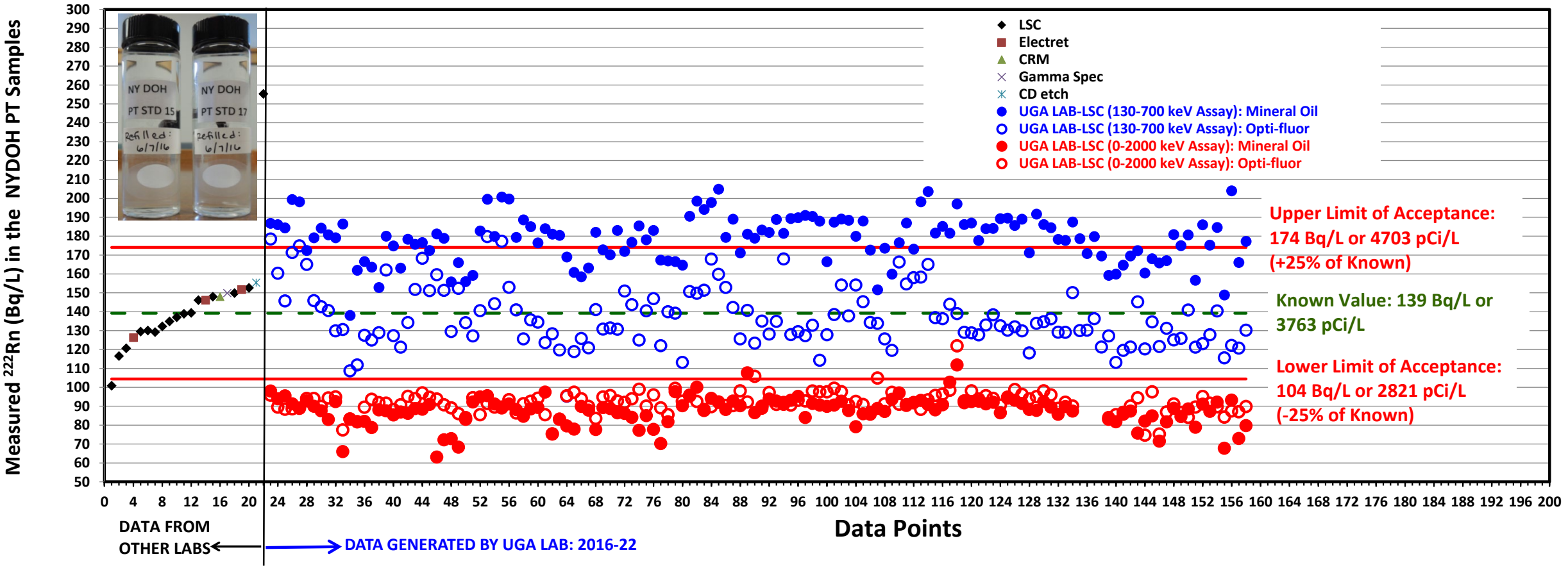
Accuracy


NYDOH 222Rn Standard Samples: Analyzed During 2016-22 (n = 68)
Known/Theoretical 222Rn Conc.: 139 Bq/L or 3,763 pCi/L
Measured Mean 222Rn Conc. (Bq/L)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
Simultaneous Drawing in Mineral Oil
Separate Drawing in Mineral Oil
Simultaneous Drawing in Opti-Fluor
Separate Drawing in Opti-Fluor
85f
92e
91e
95d
176b
184a
139c
138c
Full-spectrum Assay (0-2000 keV)
ROI Assay (130-700 keV)

NYDOH PT Samples: Accuracy of Measurements At a Glance

Radon levels in the NYDOH proficiency testing standard samples in 34 duplicate measurements (34 x Dup. x 2 different Sample Prep = 136 data points in each case) at around 40-50-day interval during **2016-2022** at the University of Georgia (UGA) laboratory to compare:

- Two different LSC assays: 0 - 2000 keV *versus* 130 - 700 keV.
- Two different scintillation fluids: mineral oil *versus* opti-fluor.



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Long-Term Evaluation of a Reusable Radon-in-Water Proficiency Test

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A Remarkable Review Comment

From: Jose Luis Gutierrez Villanueva via Open Journal Systems <journals-noreply@openacademia.net>

Sent: Friday, January 20, 2023 4:24 AM

To: Uttam KAMAR SAHA

Subject: [MS ID: 9149] [Journal of the European Radon Association] Editor Decision Revision

Attachments: F-9149-63741-1-5-20230113_revE.docx

The investigated topic is interesting and useful. Your group did a good work, having a lot of results from long period of time and duplicates are really precise. The idea to use reusable test is great and definitely will be used in worldwide.

The paper has just been published in September in:

Journal of the European Radon Association 2023, **4**:9149.

http://dx.doi.org/10.35815/radon.v4.9149

https://radonjournal.net/index.php/radon/article/view/9149

JERA

ORIGINAL ARTICLE

Long-term evaluation of a reusable radon-in-water proficiency test

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Abstract

A proficiency test is an integral part of any analytical procedure; however, there is no known proficiency test in place for radon-in-water analysis. This led us to conduct a long-term study. Successful preparation of a reusable radon (^{222}Rn)-in-water standard containing a 'radium (^{226}Ra)-loaded filter paper (the source)' sandwiched between polyethylene sheeting has been reported. As the source '^{226}Ra-loaded filter paper' is sandwiched between polyethylene sheets, the surrounding water (which is sampled and analyzed) in the bottle remains free of ^{226}Ra. With this type of standards, a previous study reported that at full ingrowth (>30 days), 86% of the ^{222}Rn produced by the source was emanated into the water and remained stable thereafter, and the remaining 14% was retarded by the polyethylene sheeting. We periodically measured radon-in-water in two such standard samples allowing a 40- to 50-day ingrowth interval for more than 6 years (2016–2022). In each measurement, we prepared in duplicate the cocktails in four different ways (in Mineral-oil *vs.* Optifluor in combination with two different ways of 'pipetting or sample drawing' and dispensing into the scintillation vials) and measured the radon-in-water using two different Liquid Scintillation Counting (LSC) assays: full-spectrum (0–2,000 keV) *versus* Region of Interest (ROI) for radon (ROI, 130–700 keV). A substantial number of repeated results unequivocally show that the reusable standards maintained its characteristics satisfactorily for a 6-year long period. Duplicate measurements were precise in almost all cases. We consistently observed significant differences in measured radon concentration between the two different LSC assays and between the two different scintillation fluids, but not between the two sample drawing methods. With full-spectrum assay (0–2,000 keV), both Mineral-oil and Optifluor grossly underestimated the actual radon concentration, and with ROI assay (130–700 keV), Mineral-oil overestimated the radon concentration; therefore, these should be avoided. Preparing the cocktails with Optifluor and measuring by ROI assay (130–700 keV) was the only method that consistently produced results within the acceptance window (±25% of the known), suggesting that a certain way of preparing and measuring the water samples could yield more accurate results for radon. Thus, our findings demonstrate that a proficiency test for radon-in-water using these reusable ^{226}Ra-free radon-in-water standards is a valid and valuable option, and it should be a part of radon-in-water analysis by the laboratories.

Keywords: *kiloelectric volt (keV)*; *Mineral-oil*; *Optifluor*; *proficiency test*; *radon (^{222}Rn)*; *liquid scintillation*

Alpha radiation from the consumption of radionuclides in drinking water is a significant emerging public health concern. According to the World

invisible cracks and holes in the foundation, increasing its concentration in the indoor air. When ^{222}Rn is inhaled through breathing radon-rich indoor air, it irradiates lung

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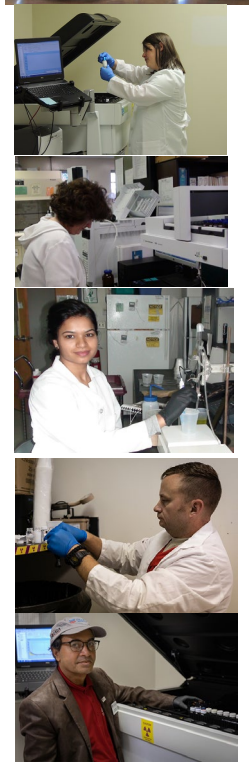
Concluding Remarks:

Potential for a Reusable Proficiency Test

2016-2023: 7 Years Rigorous Research

- ✓ **Robust** dataset
- ✓ **Disproved** the common belief
- ✓ **Proficiency test** for radon in water is indeed possible
- ✓ **Eliminating the uncertainty** in this critical aspect



International Attention

Canadian Association of Radon Scientists and Technologists

International Attention

UGA Radon Team