Underground Rock Types and Their Association with Indoor Air Radon and Lung Cancer Risk in Georgia

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Background of the Study

- **Mapping of radon in indoor air and well water in Georgia.**

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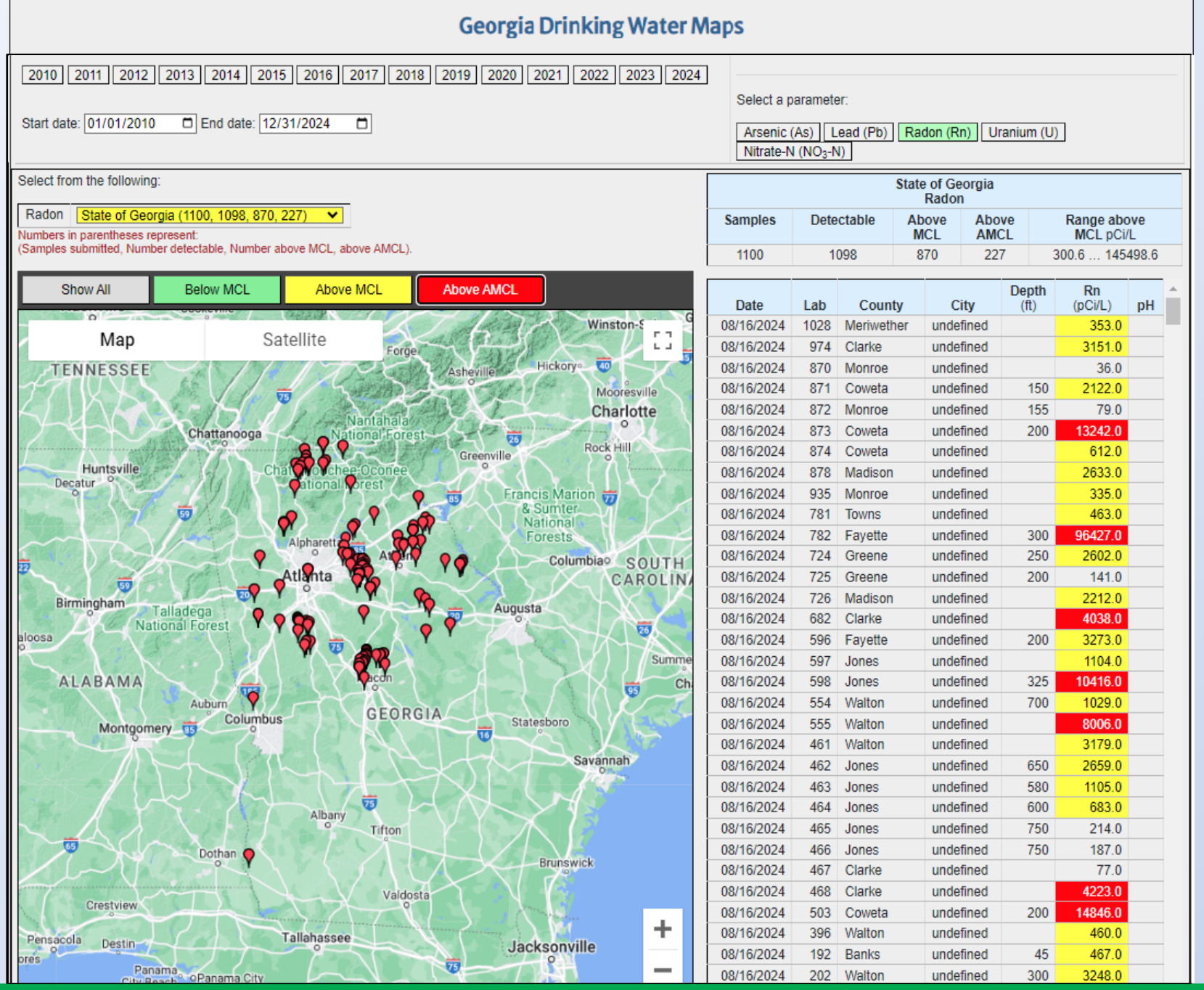
Agricultural and Environmental Services Laboratories

Mapping Radon in Well Water

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



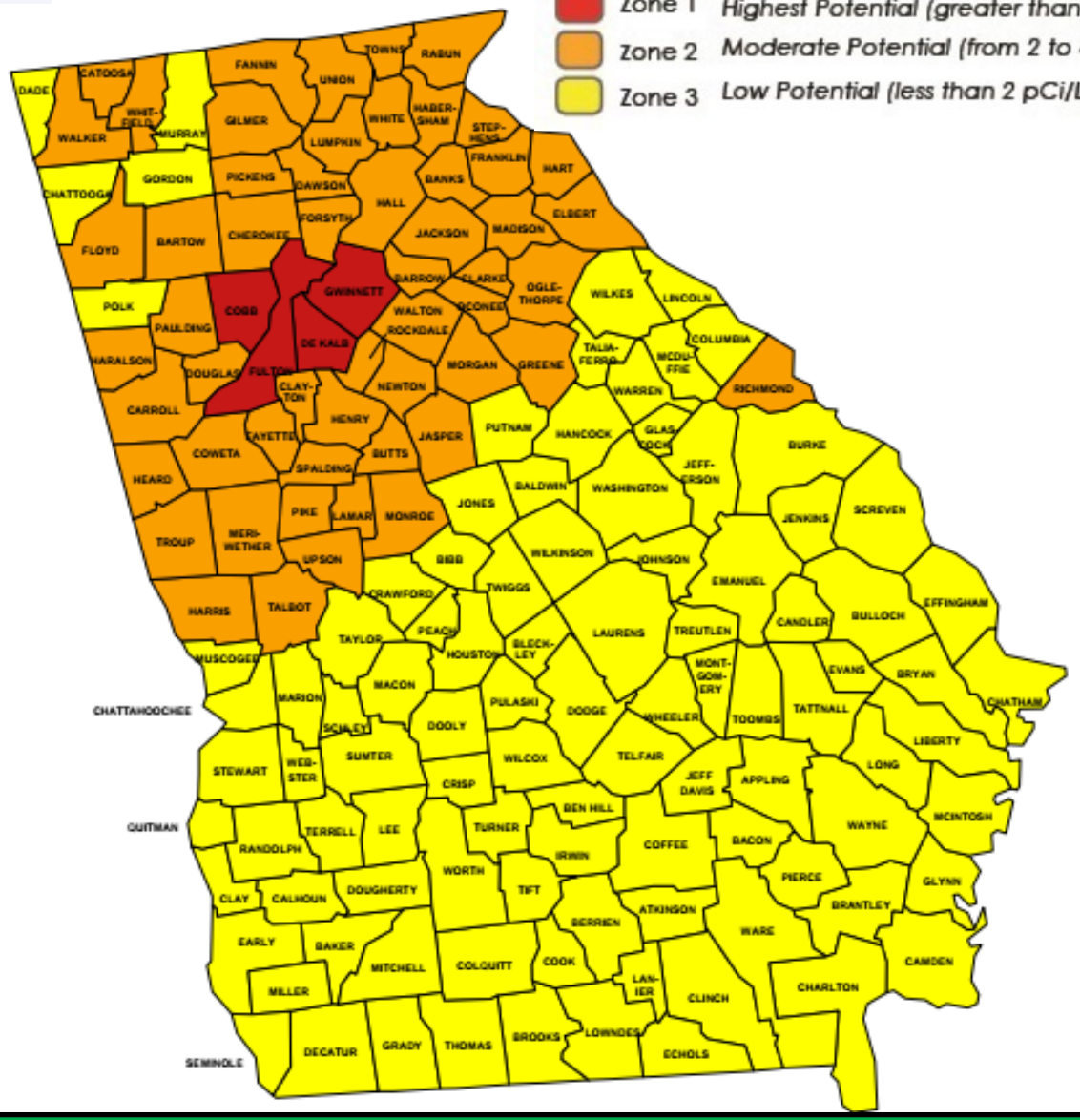
State of Georgia Radon

Samples	Detectable	Above MCL	Above AMCL	Range above MCL pCi/L
1100	1098	870	227	300.6 … 145498.6

Date	Lab	County	City	Depth (ft)	Rn (pCi/L)	pH
08/16/2024	1028	Meriwether	undefined		353.0	
08/16/2024	974	Clarke	undefined		3151.0	
08/16/2024	870	Monroe	undefined		36.0	
08/16/2024	871	Coweta	undefined	150	2122.0	
08/16/2024	872	Monroe	undefined	155	79.0	
08/16/2024	873	Coweta	undefined	200	13242.0	
08/16/2024	874	Coweta	undefined		612.0	
08/16/2024	878	Madison	undefined		2633.0	
08/16/2024	935	Monroe	undefined		335.0	
08/16/2024	781	Towns	undefined		463.0	
08/16/2024	782	Fayette	undefined	300	96427.0	
08/16/2024	724	Greene	undefined	250	2602.0	
08/16/2024	725	Greene	undefined	200	141.0	
08/16/2024	726	Madison	undefined		2212.0	
08/16/2024	682	Clarke	undefined		4038.0	
08/16/2024	596	Fayette	undefined	200	3273.0	
08/16/2024	597	Jones	undefined		1104.0	
08/16/2024	598	Jones	undefined	325	10416.0	
08/16/2024	554	Walton	undefined	700	1029.0	
08/16/2024	555	Walton	undefined		8006.0	
08/16/2024	461	Walton	undefined		3179.0	
08/16/2024	462	Jones	undefined	650	2659.0	
08/16/2024	463	Jones	undefined	580	1105.0	
08/16/2024	464	Jones	undefined	600	683.0	
08/16/2024	465	Jones	undefined	750	214.0	
08/16/2024	466	Jones	undefined	750	187.0	
08/16/2024	467	Clarke	undefined		77.0	
08/16/2024	468	Clarke	undefined		4223.0	
08/16/2024	503	Coweta	undefined	200	14846.0	
08/16/2024	396	Walton	undefined		460.0	
08/16/2024	192	Banks	undefined	45	467.0	
08/16/2024	202	Walton	undefined	300	3248.0	

GEORGIA - EPA Map of Radon Zones

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



Radon Levels in Georgia Counties*

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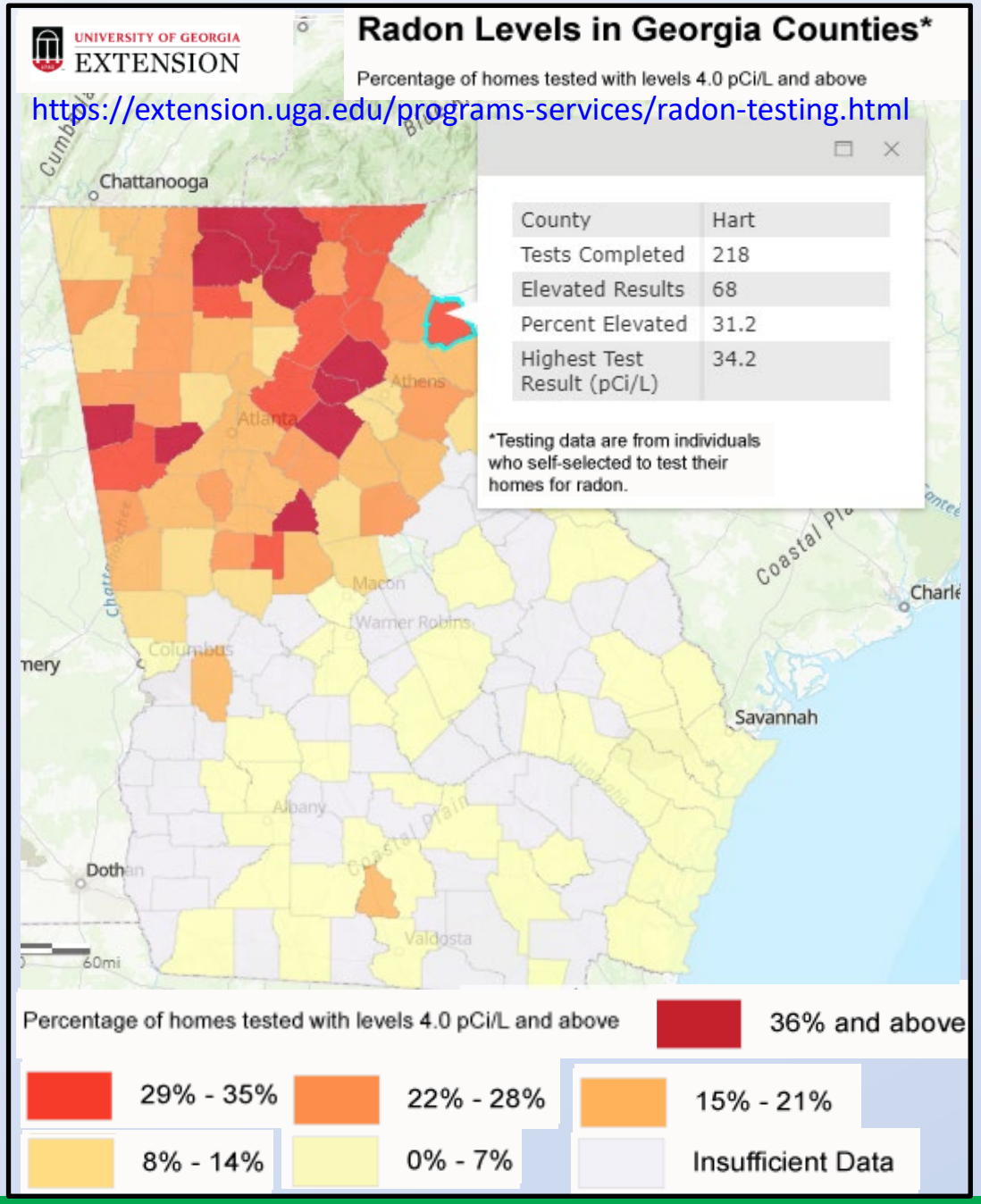
Percentage of homes tested with levels 4.0 pCi/L and above

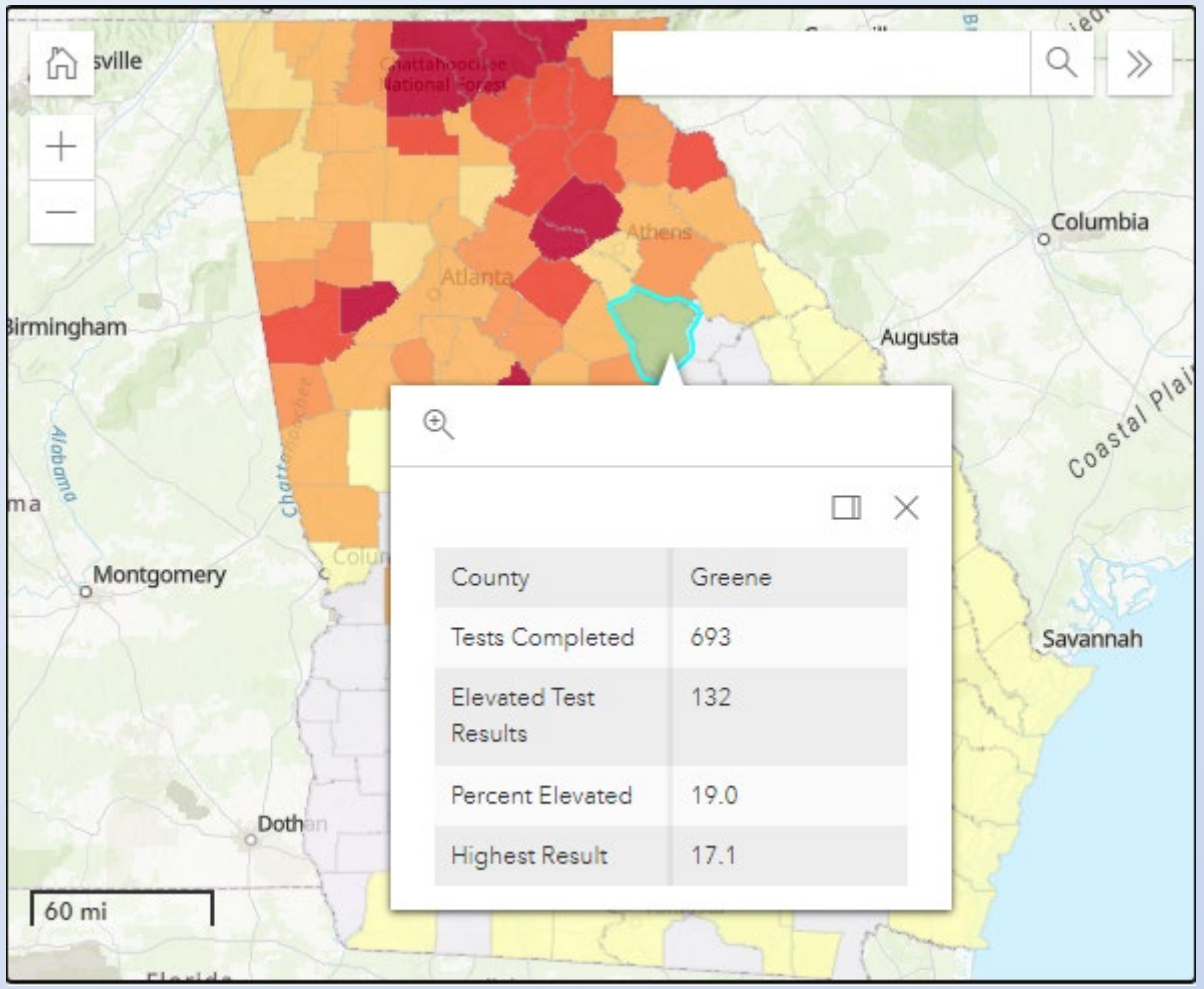
https://extension.uga.edu/programs-services/radon-testing.html



Georgia radon map updated with data through 2022

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

- 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

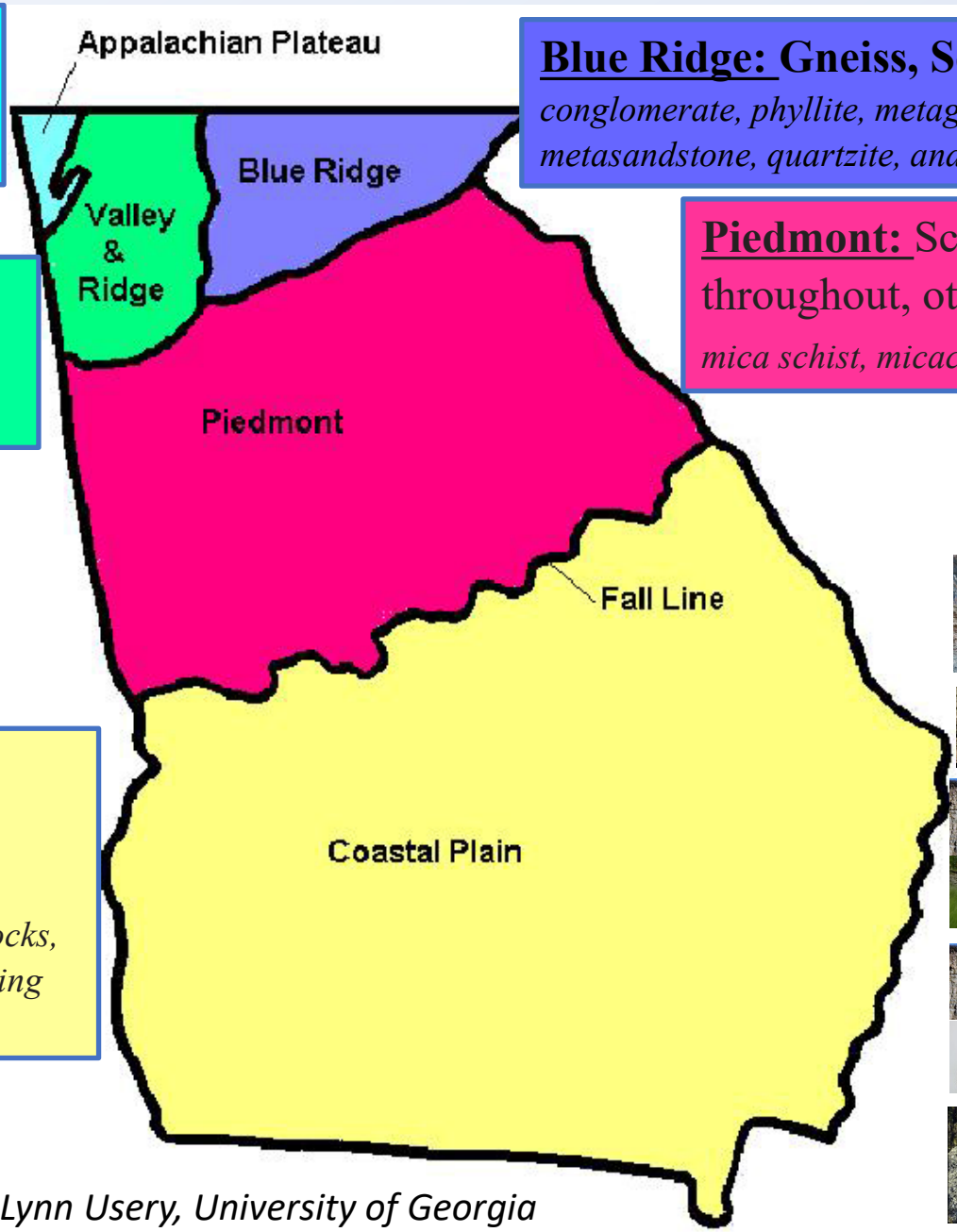


This Huge Dataset:
Association of Indoor Air Radon and Lung Cancer Risk with Underground Rock Types in Georgia

<u>Appalachian Plateau:</u> Limestone, Sandstone, Shale, Siltstone, *conglomerate, and coal-bearing strata.*

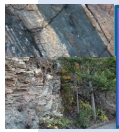
<u>Valley and Ridge:</u> Limestone, Dolomite, Shale, Siltstone, and Sandstone, *chert, mudstone, and marble.*

<u>Coastal Plain:</u> up to 7,000 feet of Poorly Consolidated Marine Clay, Silt, and Sand *above the basement rocks consist entirely of igneous and metamorphic rocks, chiefly granites, gneisses, and schists, resembling those of the Piedmont region.*

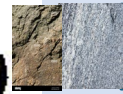


<u>Blue Ridge:</u> Gneiss, Schist, Quartzite, Slate, *conglomerate, phyllite, metagraywacke, metasiltstone, metasandstone, quartzite, and saprolite.*

<u>Piedmont:</u> Scattered **Granite** outcrops throughout, others mostly **Gneiss & Schist,** *mica schist, micaceous saprolite, biotite gneiss.*



<u>Blue Ridge:</u>
Gneiss, Schist, Quartzite, Slate with some *conglomerate, phyllite, etc.*



<u>Piedmont:</u>
Granite *with some Gneiss & Schist*

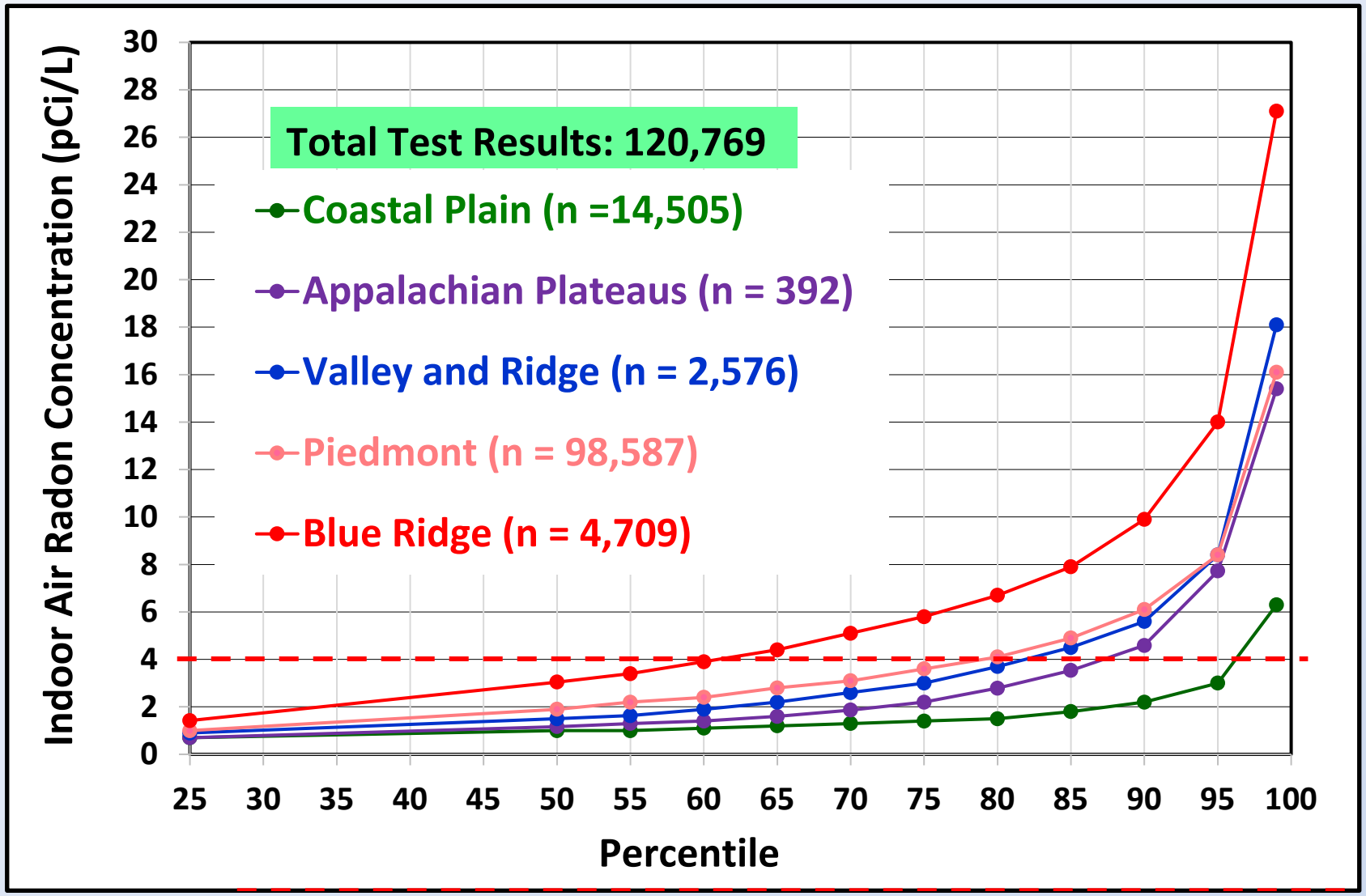
<u>Valley and Ridge:</u>
Limestone, Dolomite, Shale, Siltstone, and Sandstone *with some chert, mudstone, and marble.*

<u>Appalachian Plateau:</u>
Limestone, Sandstone, Shale, Siltstone *with some conglomerate, and coal-bearing strata*

<u>Coastal Plain:</u>
Poorly Consolidated Marine Clay, Silt, and Sand *above the basement rocks*

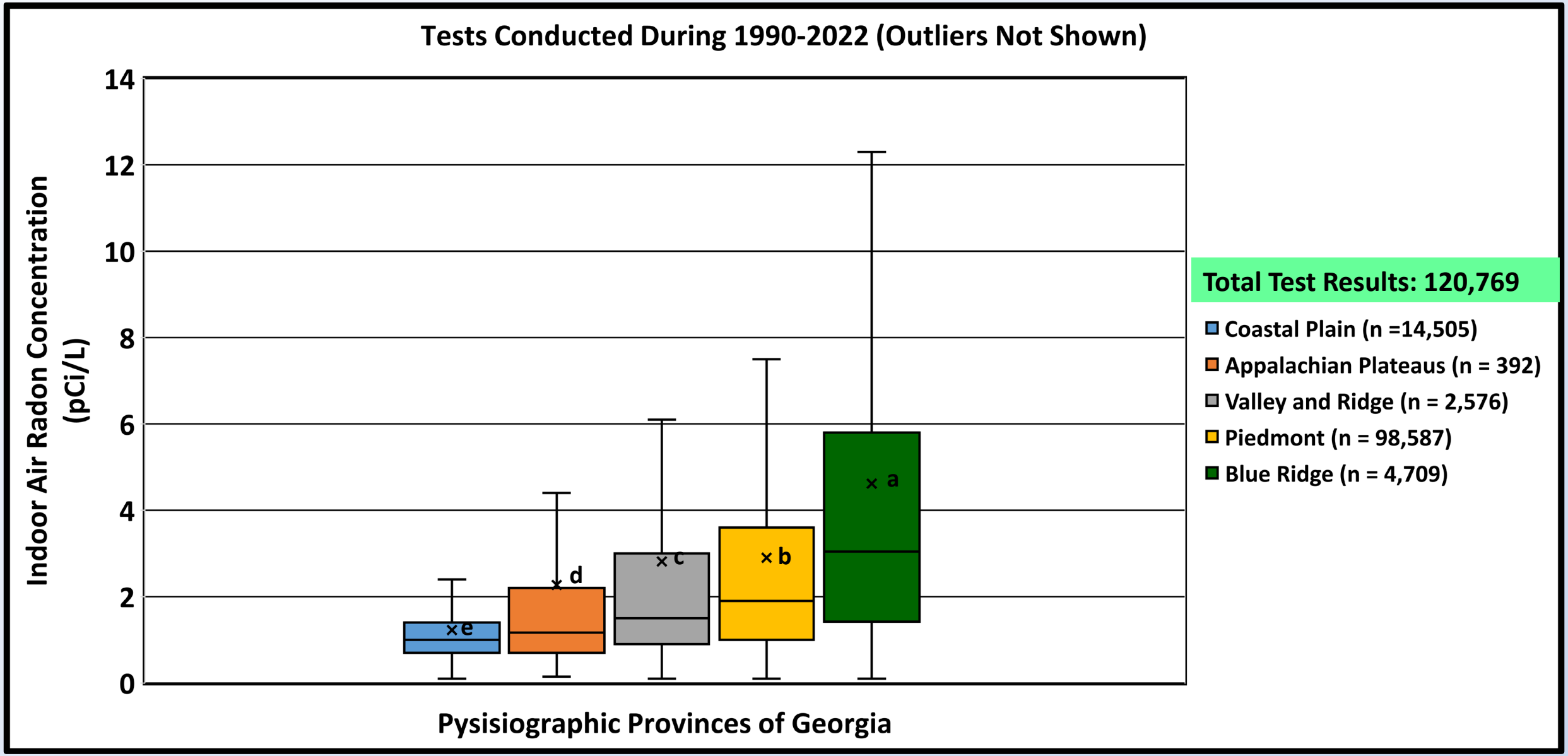
Map Source: "Geographic Regions of Georgia" by E. Lynn Usery, University of Georgia

Spread of Indoor Air Radon Test Results (1990-2022) in Different Physiographic Units of Georgia



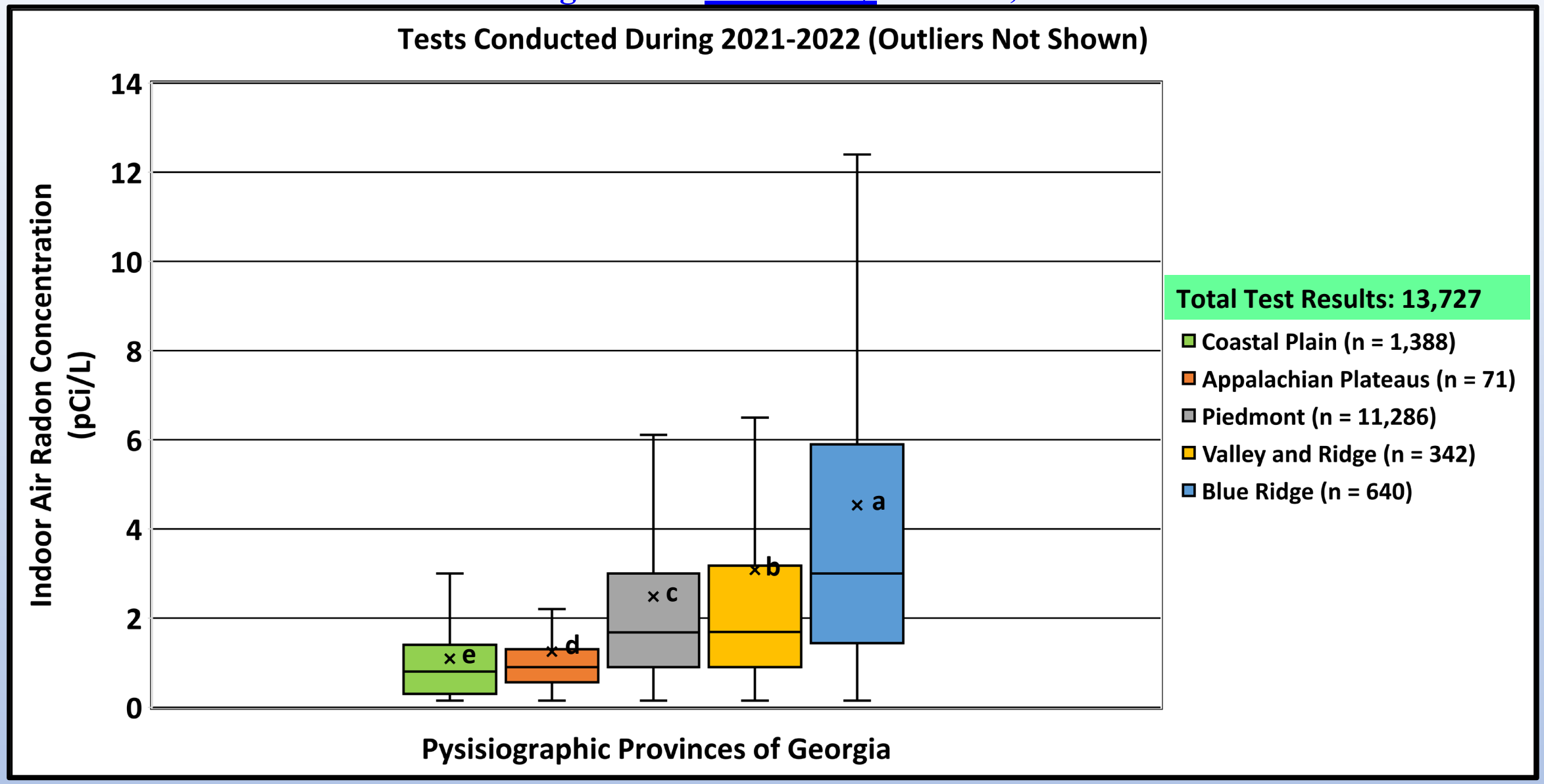
Indoor Air Radon Concentration in GA: Boxplots

Testing Period: 1990-2022; Total: 120,769



Indoor Air Radon Concentration in GA: Boxplots

Testing Period: 2021-2022; Total: 13,727

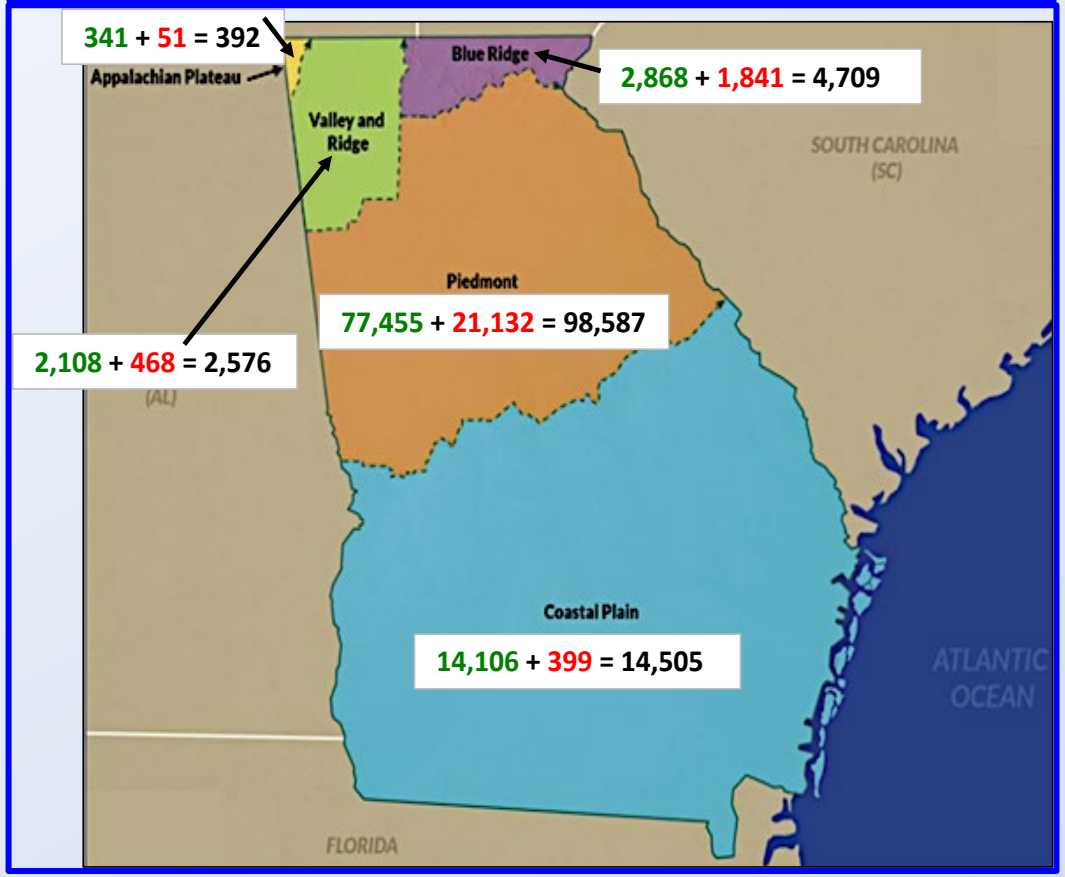


Bivariate Association:

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

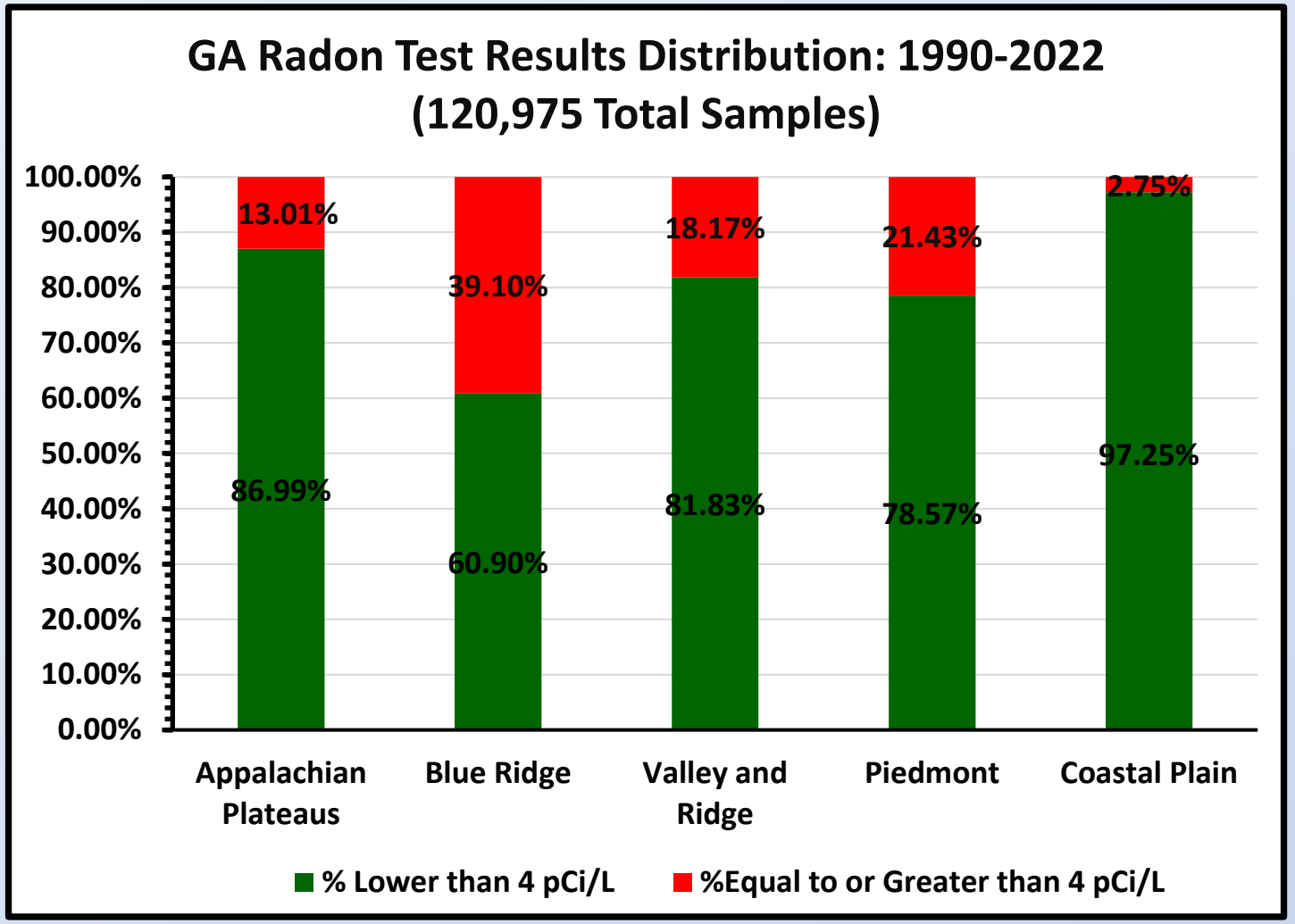
GA Radon Test Results: 1990-2022
Total: 120,769

- Green: Test results Lower than 4 pCi/L
- Red: 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 = 120,769) = 3,943.5, p < 0.00001



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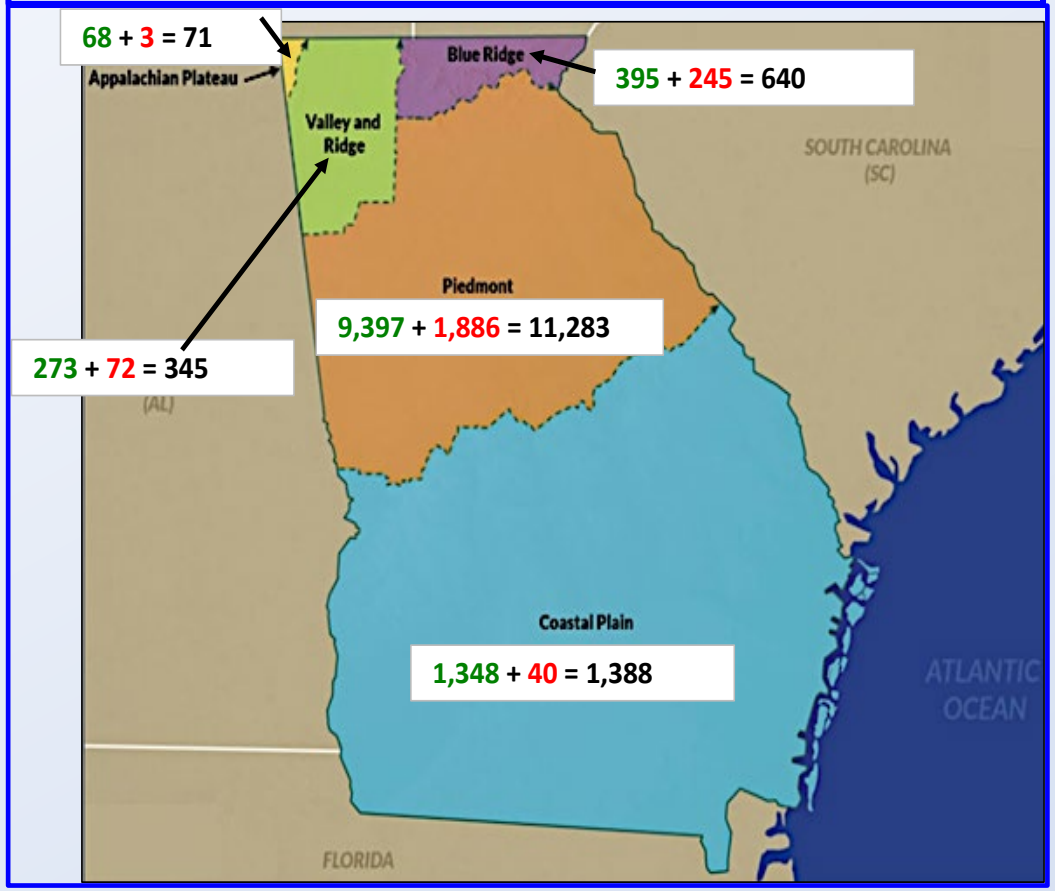
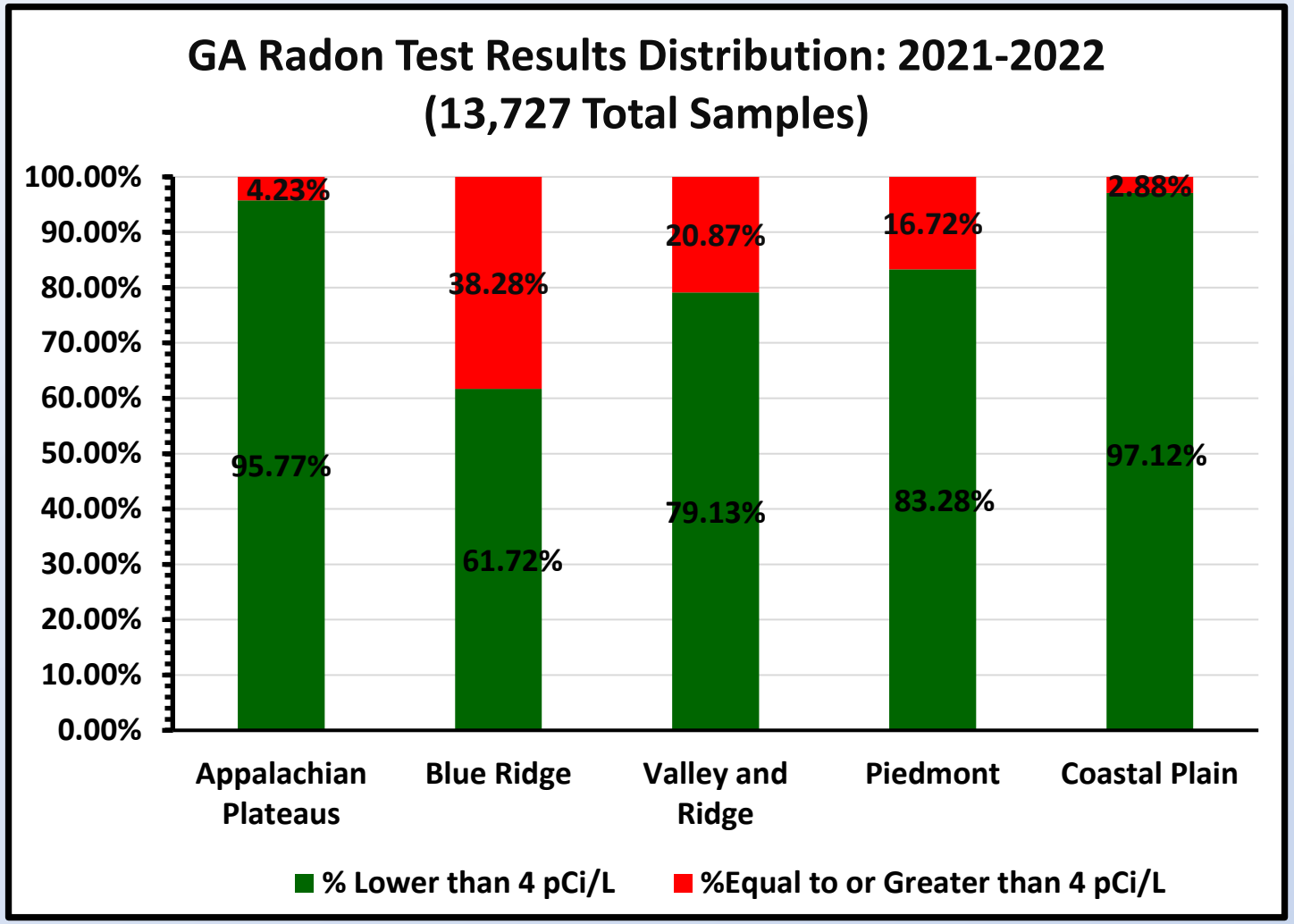


Chi-Square Test: Association of the Distribution with the Physiographic Provinces

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



Odds Ratio and Relative Risk

(of Indoor Air Radon Level ≥4.0 pCi/L)

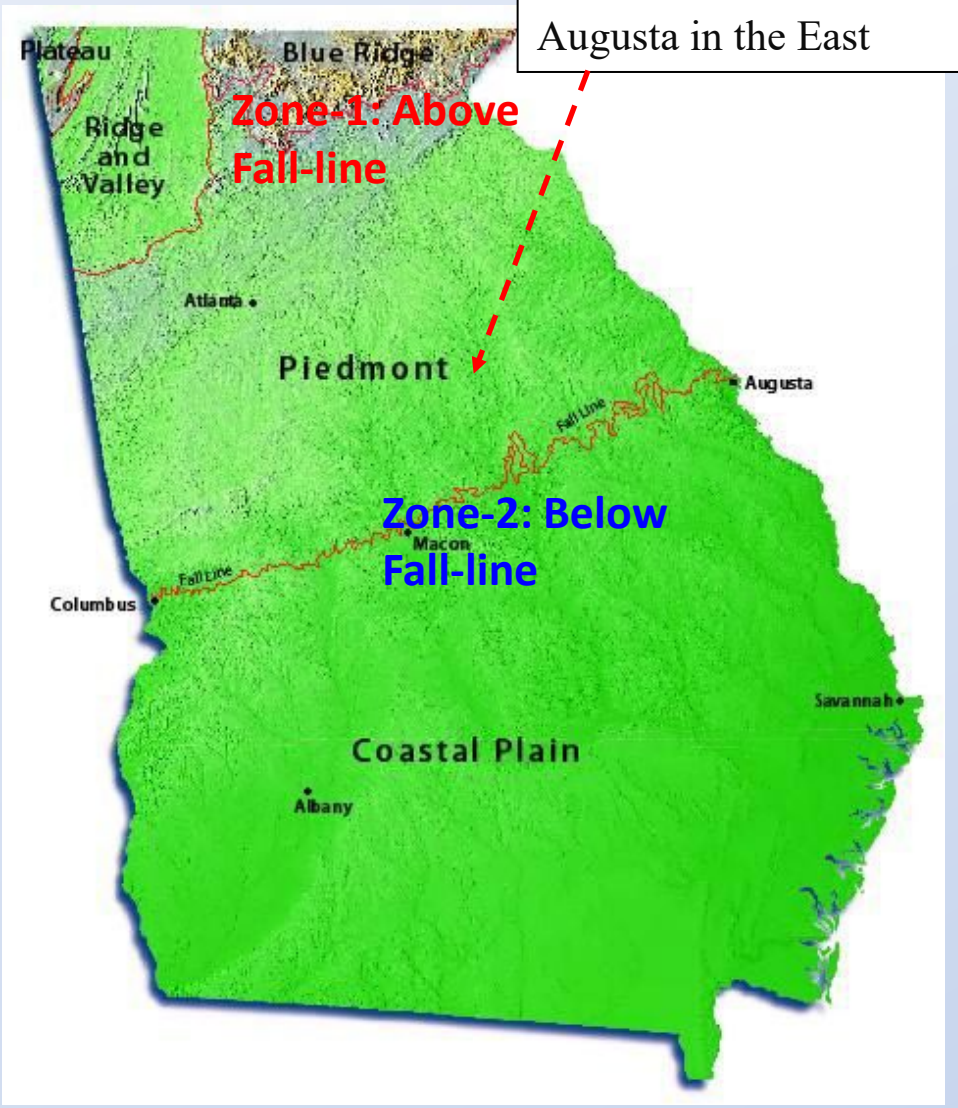
Zone	Number of Test Results Equal to or Greater than 4 pCi/L	Number of Test Results Lower than 4 pCi/L
Zone-1 (above fall-line)	A	B
Zone-2 (above fall-line)	C	D

Odds Ratio $_{\text{(Zone-1 over Zone-2)}} = (A \div B) \div (C \div D)$

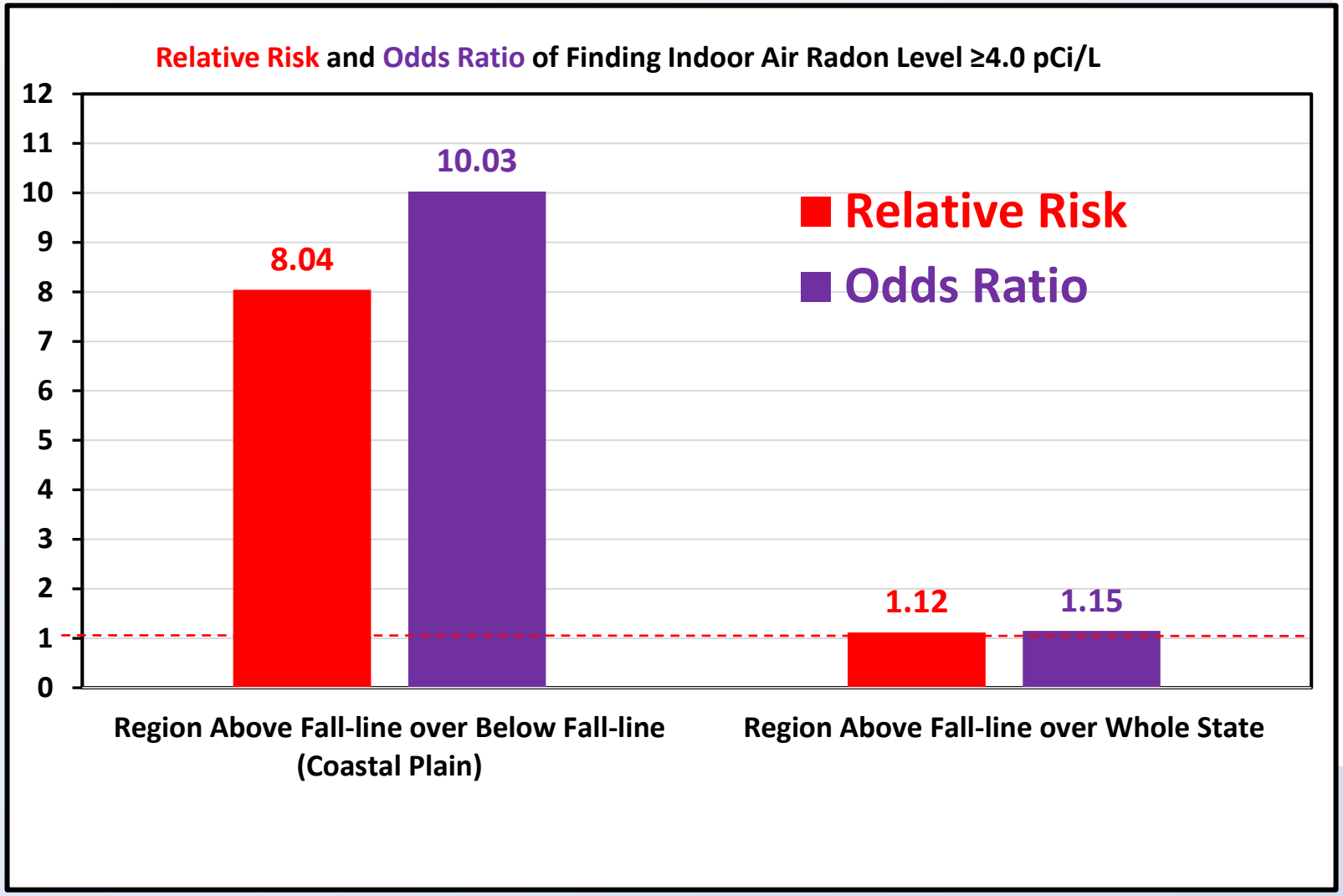
Relative Risk $_{\text{(Zone-1 over Zone-2)}} = [A/(A+B)] \div [C/(C+D)]$

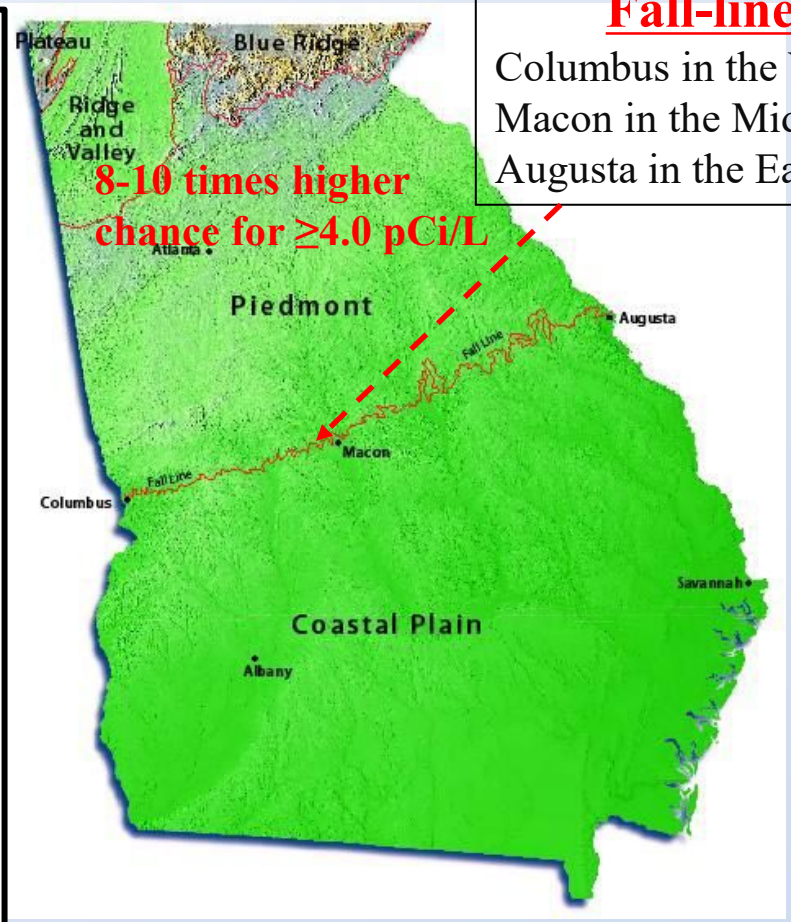
Fall-line

Columbus in the West
Macon in the Middle
Augusta in the East



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





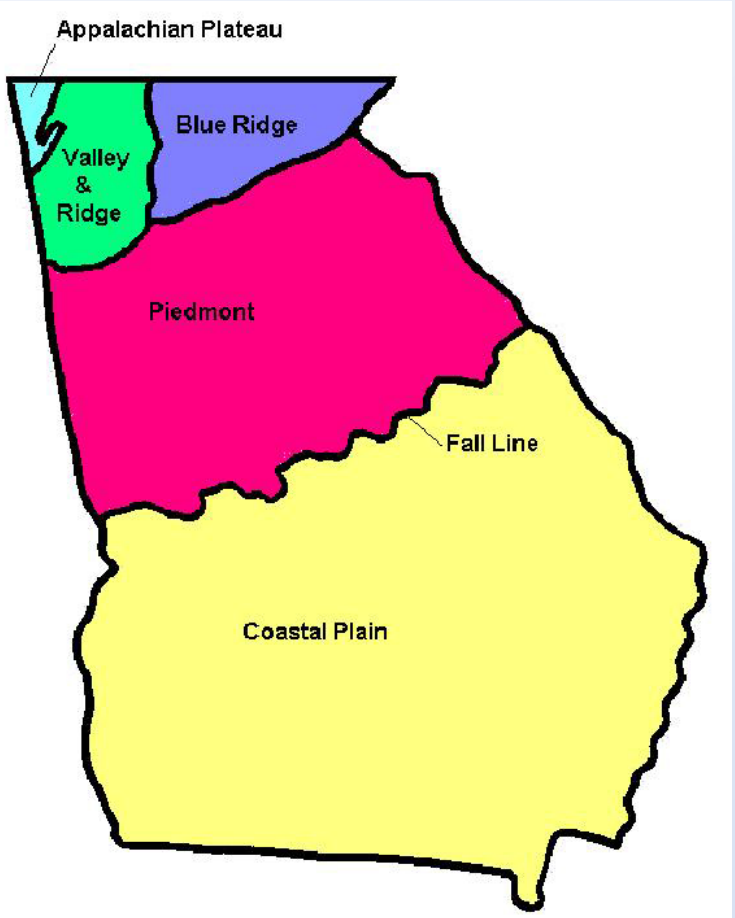
Fall-line

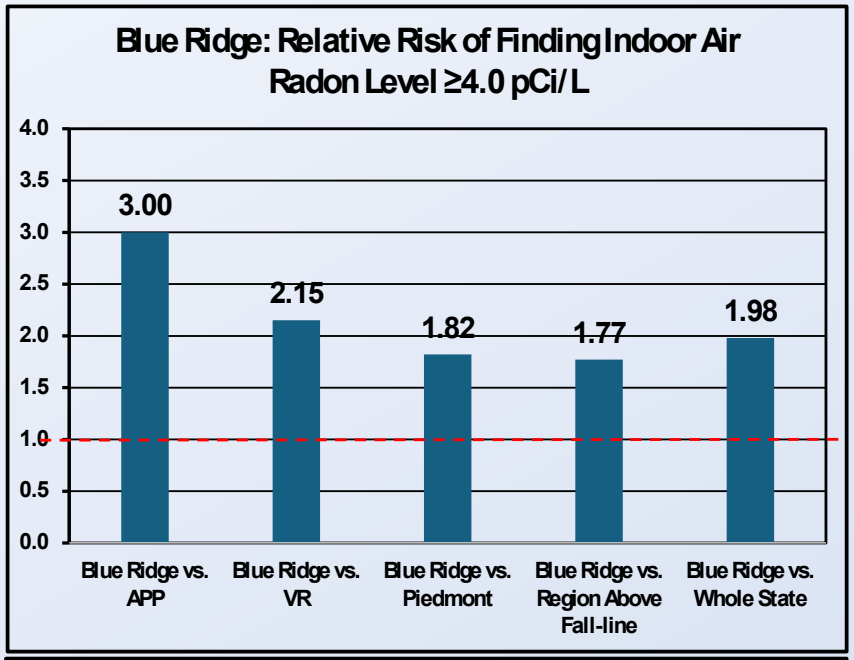
Columbus in the West
Macon in the Middle
Augusta in the East

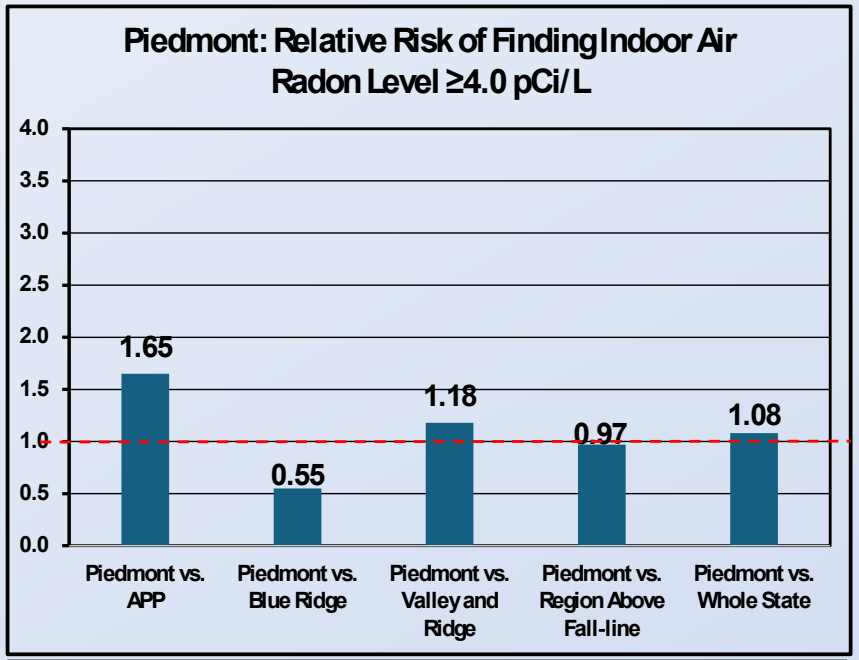
The chances of getting equal to or greater than 4.0 pCi/L test results are 8-10 times higher in the area above the fall-line than below the fall-line.

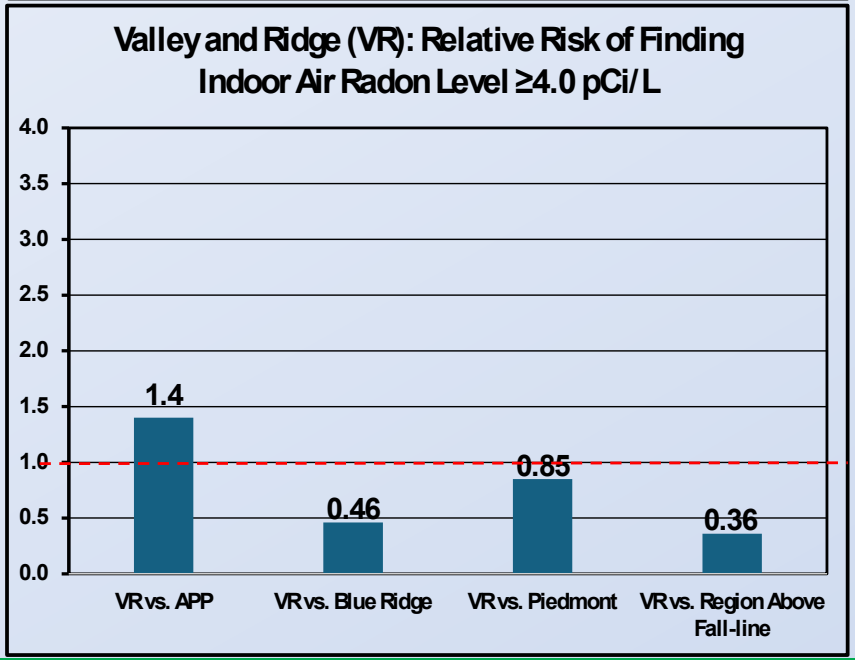
Areas Above Fall-line:

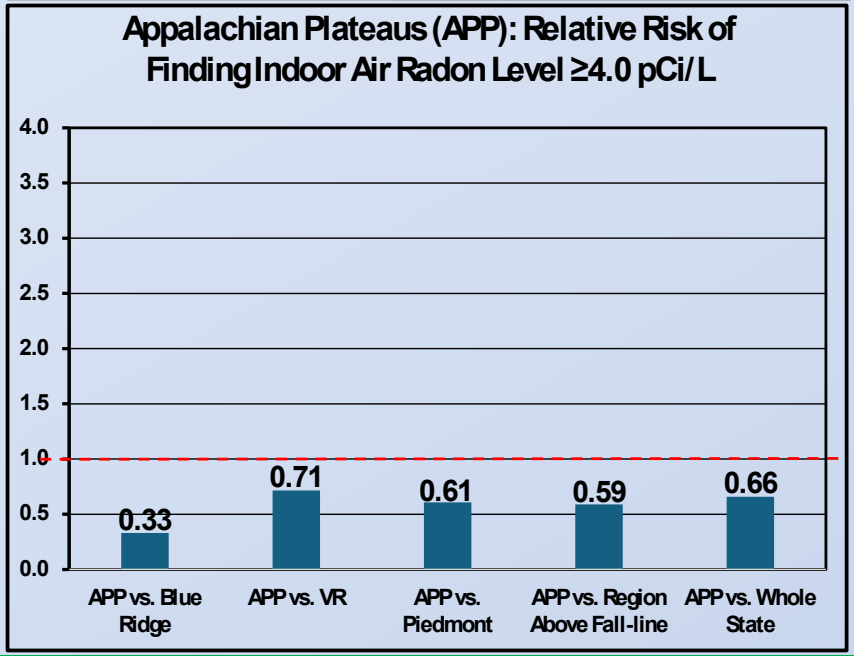
Relative Risk of Finding Indoor Air Radon Level ≥4.0 pCi/L Within 4 Physiographic Units





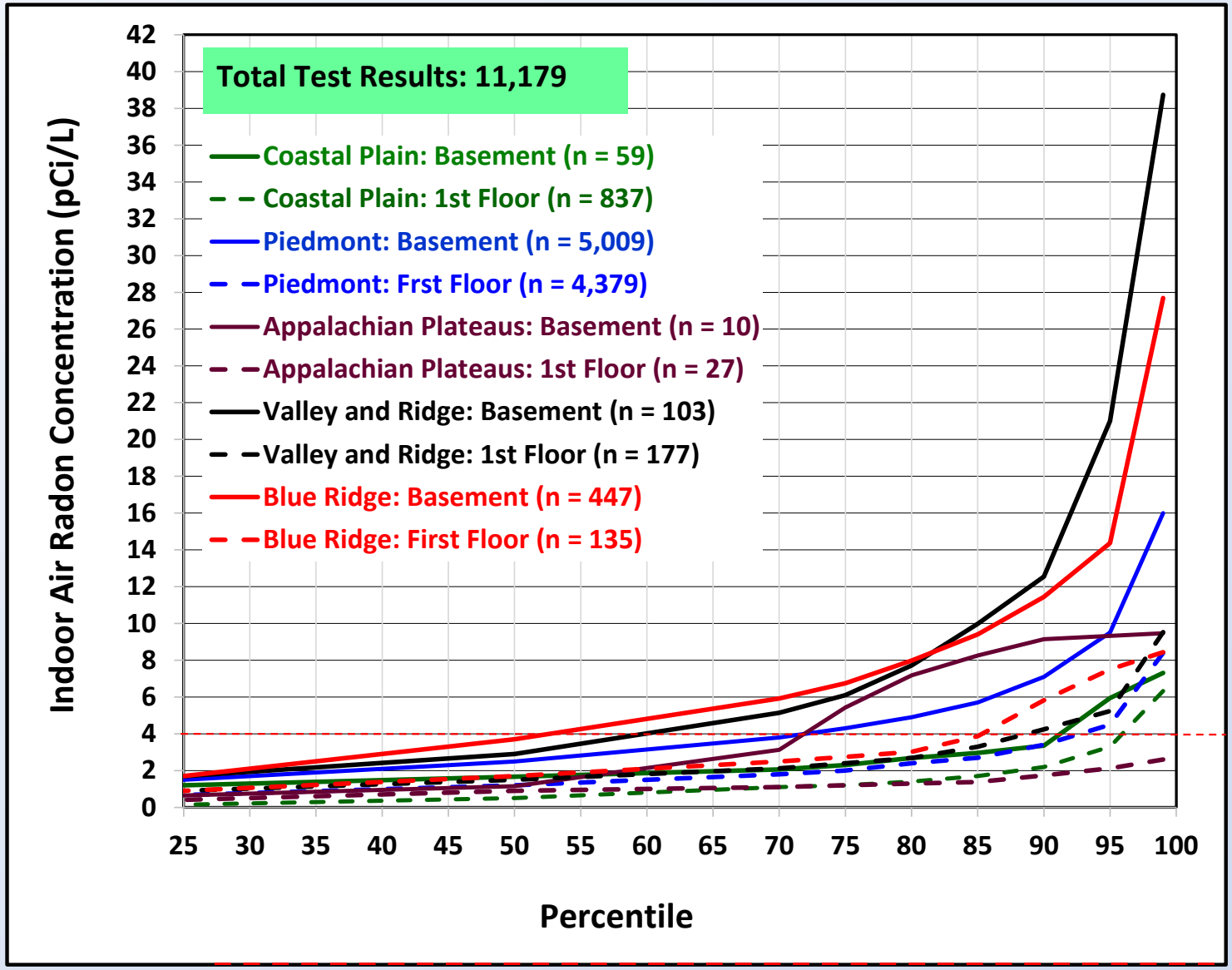






Indoor Air Radon Concentration: Basement vs. First/Main Floor

GA Radon Test Results: 2021-2022; Total: 11,179



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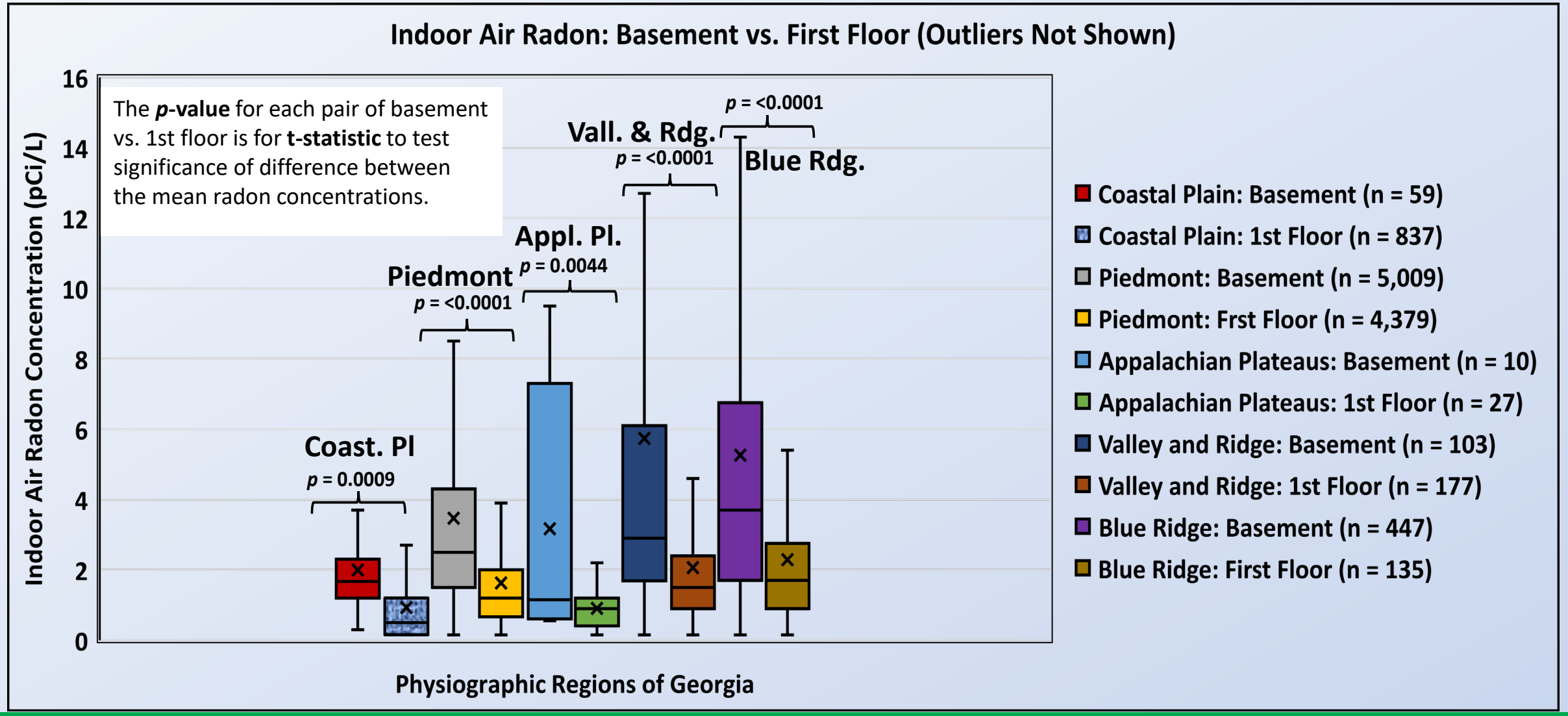


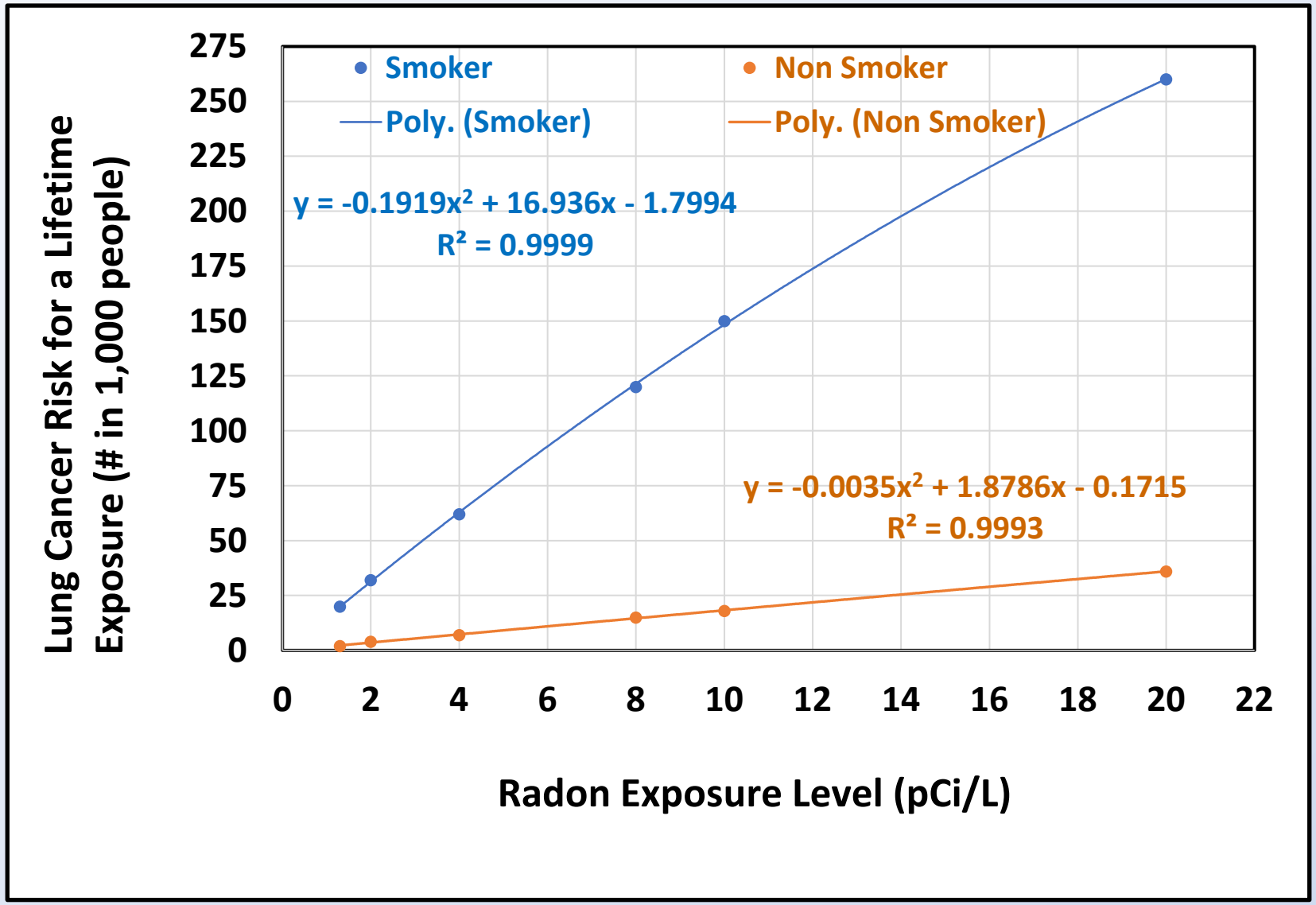
Potential Lung Cancer Risk – Radon

- **Leading cause of lung cancer, after smoking.**
- **US Surgeon General – Health Advisory of 4 pCi/L in Homes (2005).**
- **For carcinogenic risk assessment, 1 in 10,000 is considered the maximum acceptable carcinogenic risk.**

Radon Level	Smoked	Never Smoked
20 pCi/L	260 in 1,000	23 in 1,000
10 pCi/L	150 in 1,000	18 in 1,000
8 pCi/L	120 in 1,000	15 in 1,000
4 pCi/L	**62 in 1,000**	**7 in 1,000**
2 pCi/L	32 in 1,000	4 in 1,000
1.3 pCi/L	20 in 1,000	2 in 1,000
0.4 pCi/L	3 in 1,000	

Source: https://www.epa.gov/radon/health-risk-radon

Models Used for Estimating Lung Cancer Risk for the Missing Exposure Levels in the Range of 1.3-20 pCi/L



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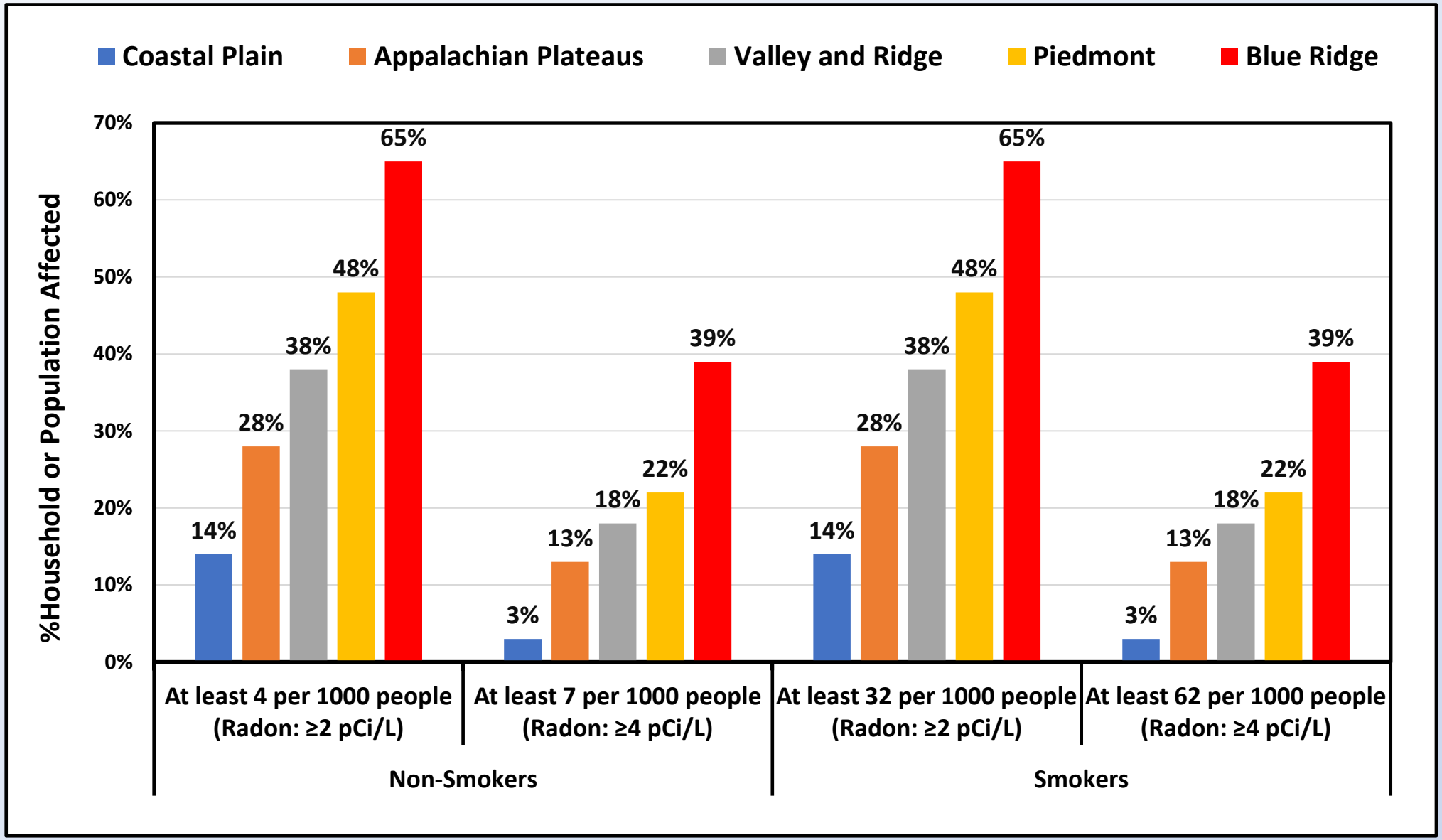
1.3 pCi/L	20 in 1,000	2 in 1,000

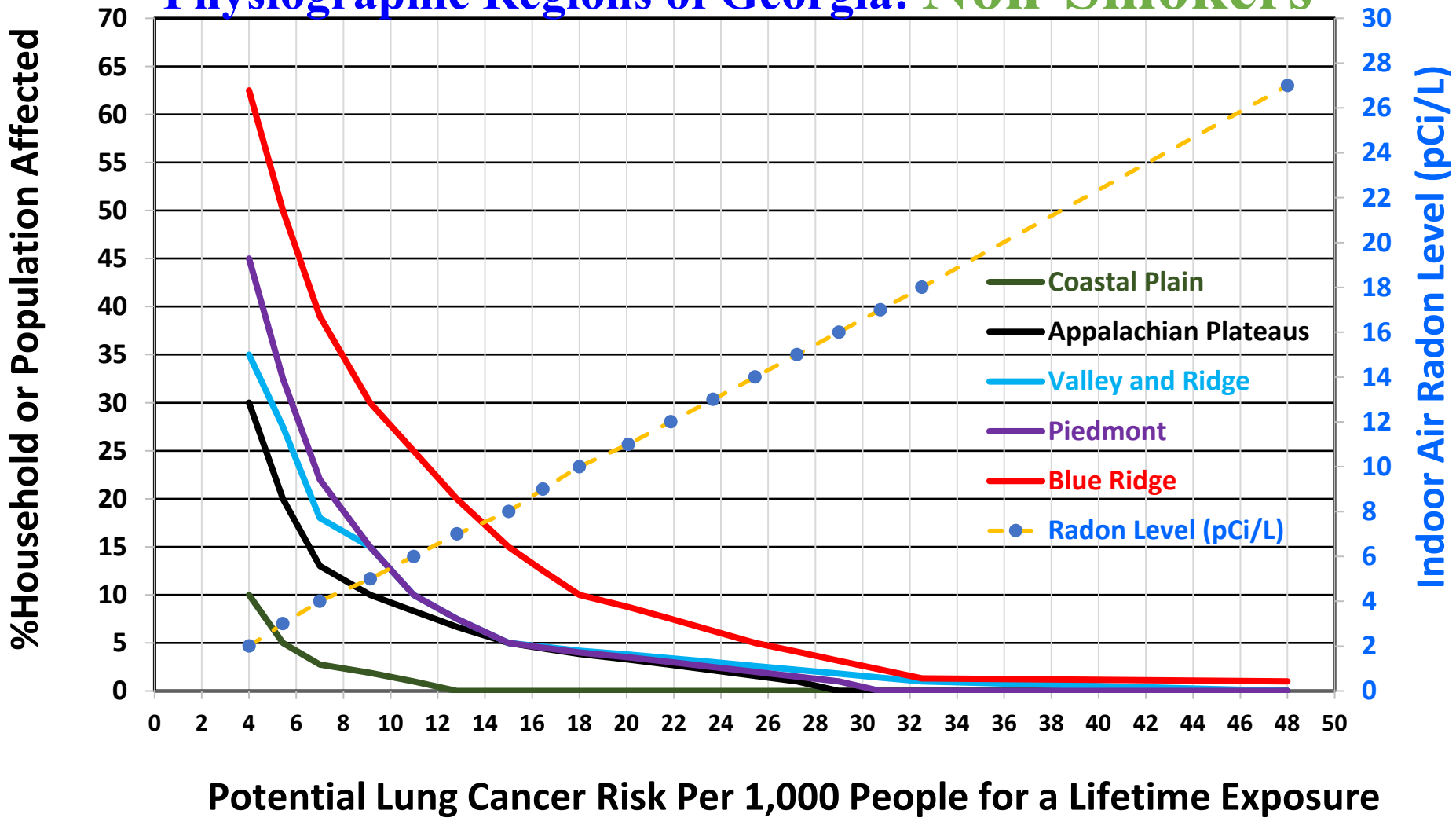
Source: https://www.epa.gov/radon/health-risk-radon

- *Probably okay for estimating the risk for the missing exposure levels in the range of 1.3-20 pCi/L.*
- *But may be questionable for exposure level outside this range.*

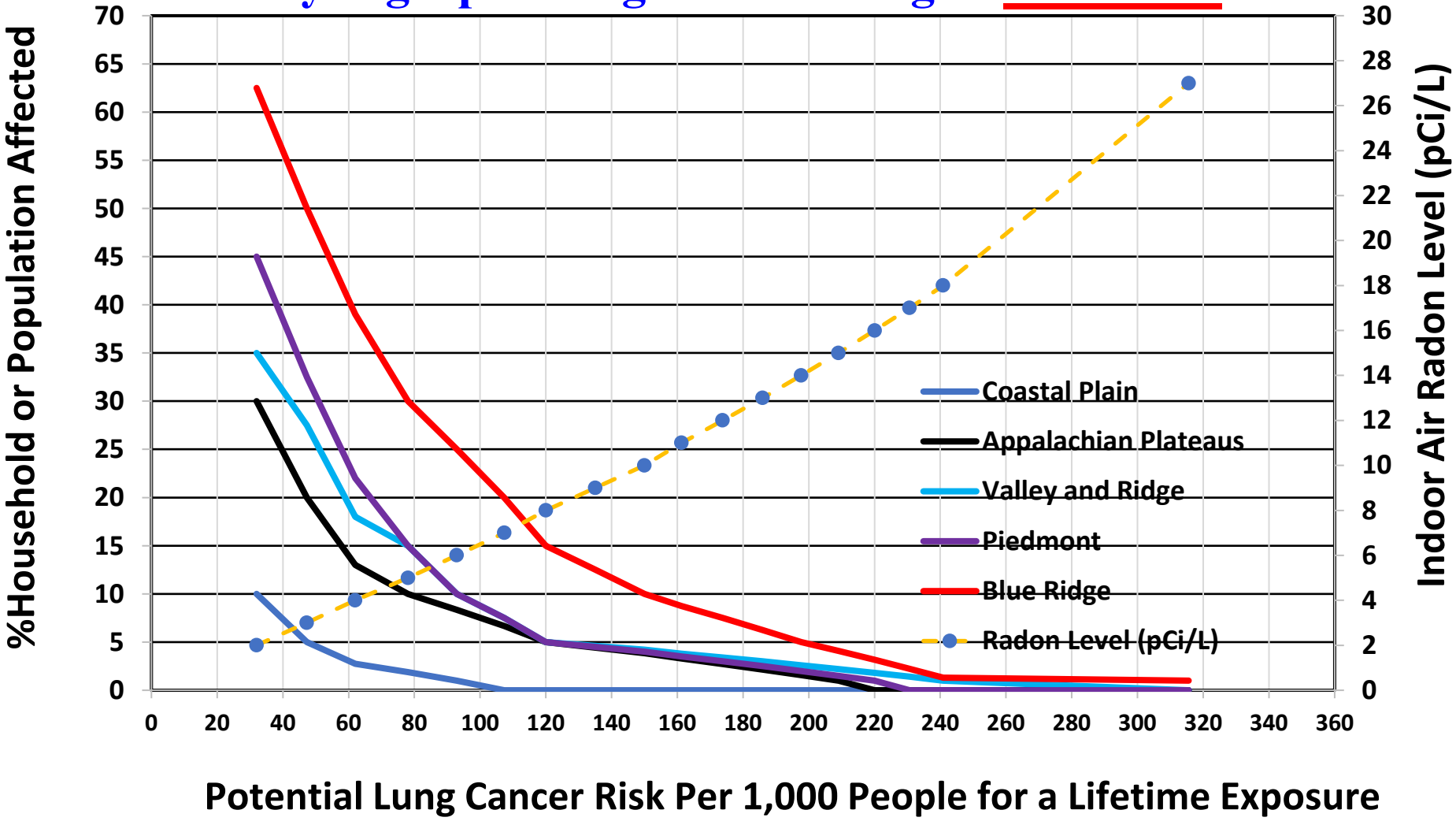
%Household/Population at Two Different Potential Lung Cancer Risk Levels



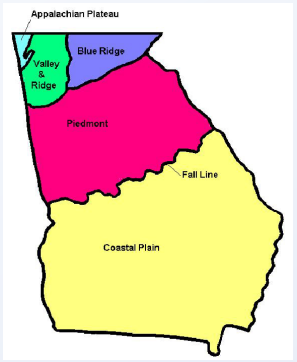
Lung Cancer Risk for a Lifetime Exposure to ^{222}Rn in Different Physiographic Regions of Georgia: Non-Smokers

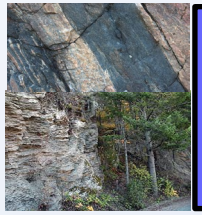


Lung Cancer Risk for a Lifetime Exposure to ^{222}Rn in Different Physiographic Regions of Georgia: Smokers

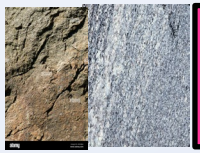


Association Summary



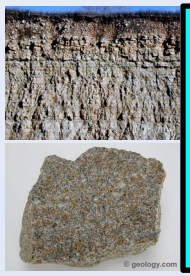


Blue Ridge:
Gneiss, Schist, Quartzite, Slate with some *conglomerate, phyllite, etc.*



Piedmont:
Granite *with some Gneiss & Schist*

Valley and Ridge:
Limestone, Dolomite, Shale, Siltstone, and Sandstone *with some chert, mudstone, and marble.*



Appalachian Plateau:
Limestone, Sandstone, Shale, Siltstone *with some conglomerate, and coal-bearing strata*

Coastal Plain:
Up to 7,000 feet Poorly Consolidated Marine Clay, Silt, and Sand *above the basement rocks*

Rn ≥4 pCi/L	Relative Risk over Whole Sate	Lung Cancer Risk (*in 1000 people*) for 10% Population
39%	1.98	At least 18 (Rn≥9.9)
22%	1.08	At least 11 (Rn≥6.1)
18%	0.92	At least 10 (Rn≥5.6)
13%	0.66	At least 8 (Rn≥4.6)
		Non-Smoker
3%	0.14	At least 4 (Rn≥2.2)

Concluding Remarks and Future Direction

- **The 5 physiographic provinces of Georgia, with contrasting underground geology, show significantly different**
  - Mean/median and spread of radon concentration.
  - Frequency of high radon.
  - Potential lung cancer risk from a lifetime exposure to radon.

- **The highest radon and the highest lung cancer risk in Georgia perhaps exist in Blue Ridge, followed by Piedmont, Valley and Ridge, and Appalachian Plateau.**

- **The lowest radon and lowest lung cancer risk was found in the coastal plain; however, still significant.**

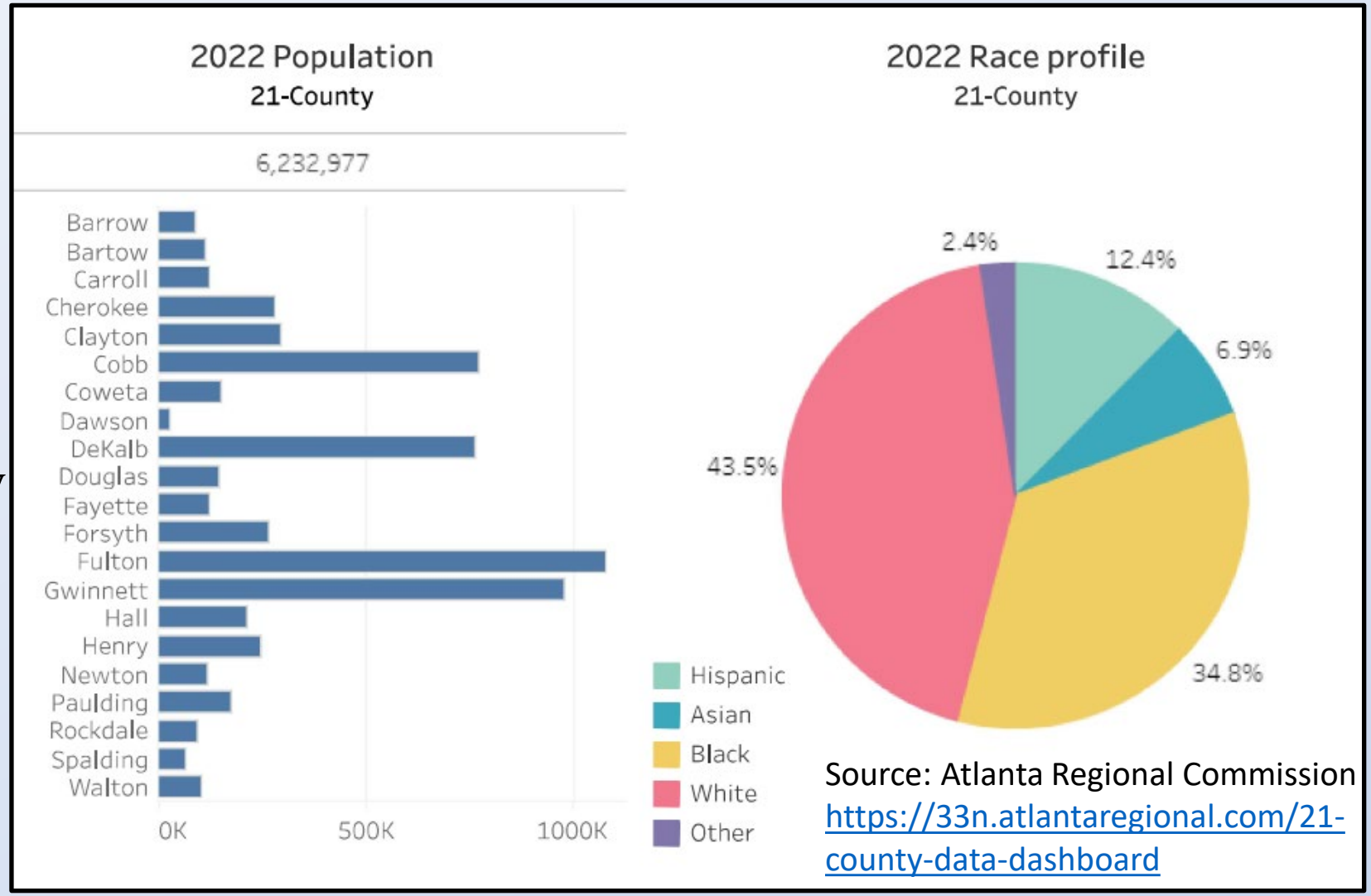
- **Population in various physiographic provinces should be considered together with these findings to properly realize the risk of radon from a public health standpoint.**

Concluding Remarks and Future Direction

Georgia population: 10.7 million.

- **6.2 million in the 21 counties of the Atlanta region.**

- **Opportunities exist to study radon testing and risk in relation to:**
  - ✓ **Urban *versus* Rural**
  - ✓ **Race**
  - ✓ **Type of building and building materials**



Source: Atlanta Regional Commission
https://33n.atlantaregional.com/21-county-data-dashboard

Thank you.

Primary contact: Dr. Uttam Saha (sahau@uga.edu)