



**pennsylvania**

DEPARTMENT OF ENVIRONMENTAL PROTECTION



Bureau of Radiation Protection

# PA Radon Program - An Update

**David J. Allard, MS, CHP**

**ISCORS Meeting**

November 9, 2015

# Disclaimer

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***Opinions of the author do not represent official policy of the DEP.***

***The author has no conflicts of interest.***

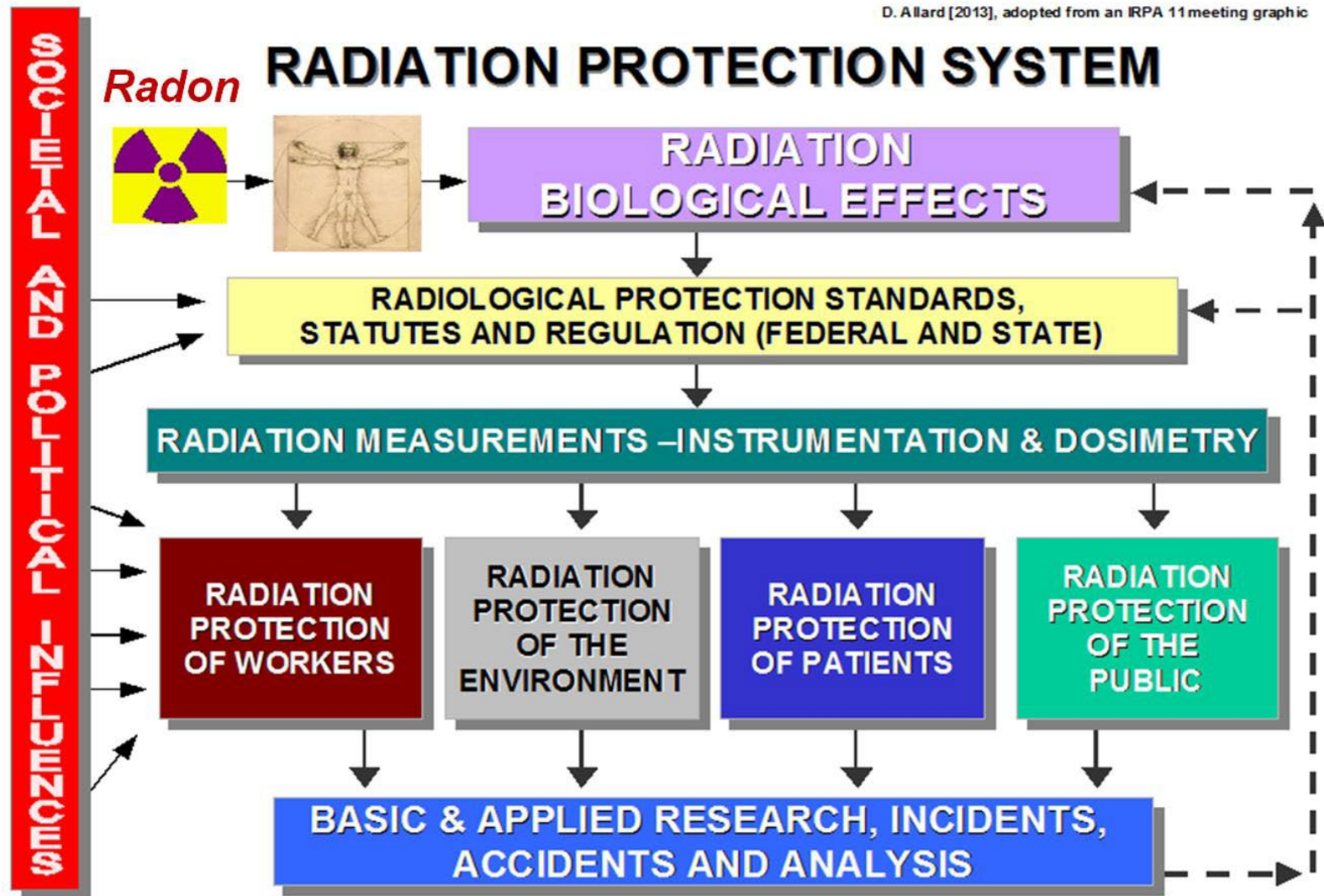
***Non-DEP images are used under 'fair use' for educational purposes.***

# Overview of This Presentation

- **Provide short history of radon in PA**
- **Review current PA Radon Program**
- **Explain radon testing and mitigation**
- **Describe a recently discovered very high Radon area, and actions taken**
- **Note ongoing radon initiatives**
- **Time for Q&A**

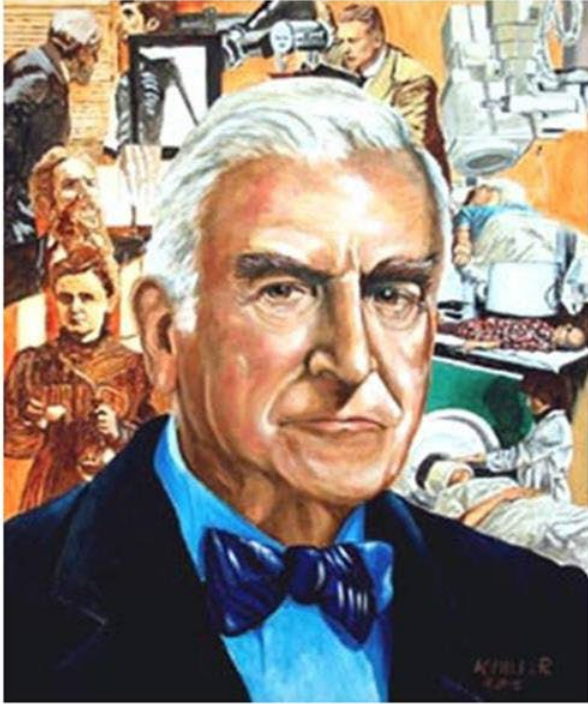
# Radiation Protection

D. Allard [2013], adopted from an IRPA 11 meeting graphic





# ▶ NCRP - Lauriston S. Taylor



Taylor painting by Ken Miller

**Radiation protection is not only a matter of science. It is a problem of philosophy, and morality, and the utmost wisdom.”**

(L.S. Taylor, 1956)

# Radon – what is it?

# Rn

86 (222)

Density  
9.73 g/L

Boiling point  
-62°C

Melting point  
-71°C

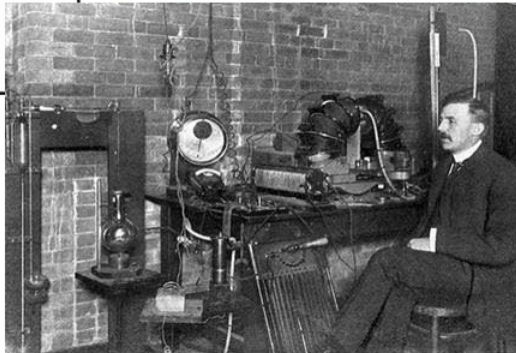
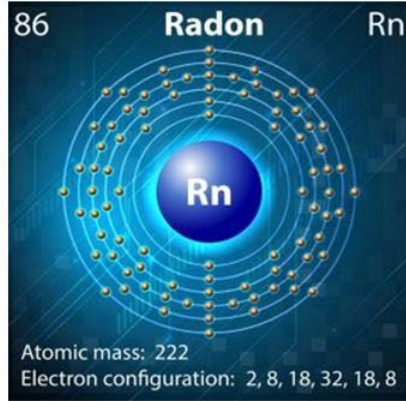
~~F.E. Dorn, 1900~~

Ernest Rutherford

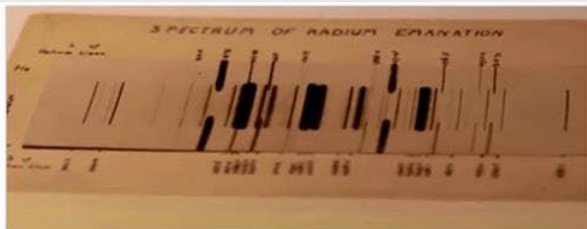
California Geological Survey  
Mineral Resources and Mineral Hazards



Emanation, Niton, Rn



Rutherford at McGill University in 1905



Emission spectrum of radon, photographed by Ernest Rutherford in 1908. Numbers at the side of the spectrum are wavelengths. The middle spectrum is of radon, while the outer two are of helium (added to calibrate the wavelengths).

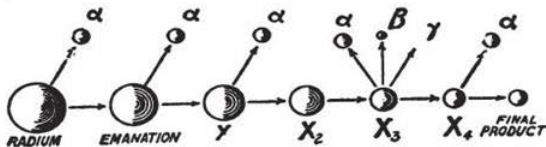


Fig. 48.—DIAGRAM TO REPRESENT THE DISINTEGRATION OF A RADIUM ATOM (AFTER RUTHERFORD).

## URANIUM 238 (U238) RADIOACTIVE DECAY



type of radiation	nuclide	half-life
	uranium-238	4.47 billion years
α	↓	
	thorium-234	24.1 days
β	↓	
	protactinium-234m	1.17 minutes
β	↓	
	uranium-234	245000 years
α	↓	
	thorium-230	8000 years
α	↓	
	radium-226	1600 years
α	↓	
	radon-222	3.823 days
α	↓	
	polonium-218	3.05 minutes
α	↓	
	lead-214	26.8 minutes
β	↓	
	bismuth-214	19.7 minutes
β	↓	
	polonium-214	0.000164 seconds
α	↓	
	lead-210	22.3 years
β	↓	
	bismuth-210	5.01 days
β	↓	
	polonium-210	138.4 days
α	↓	
	lead-206	stable



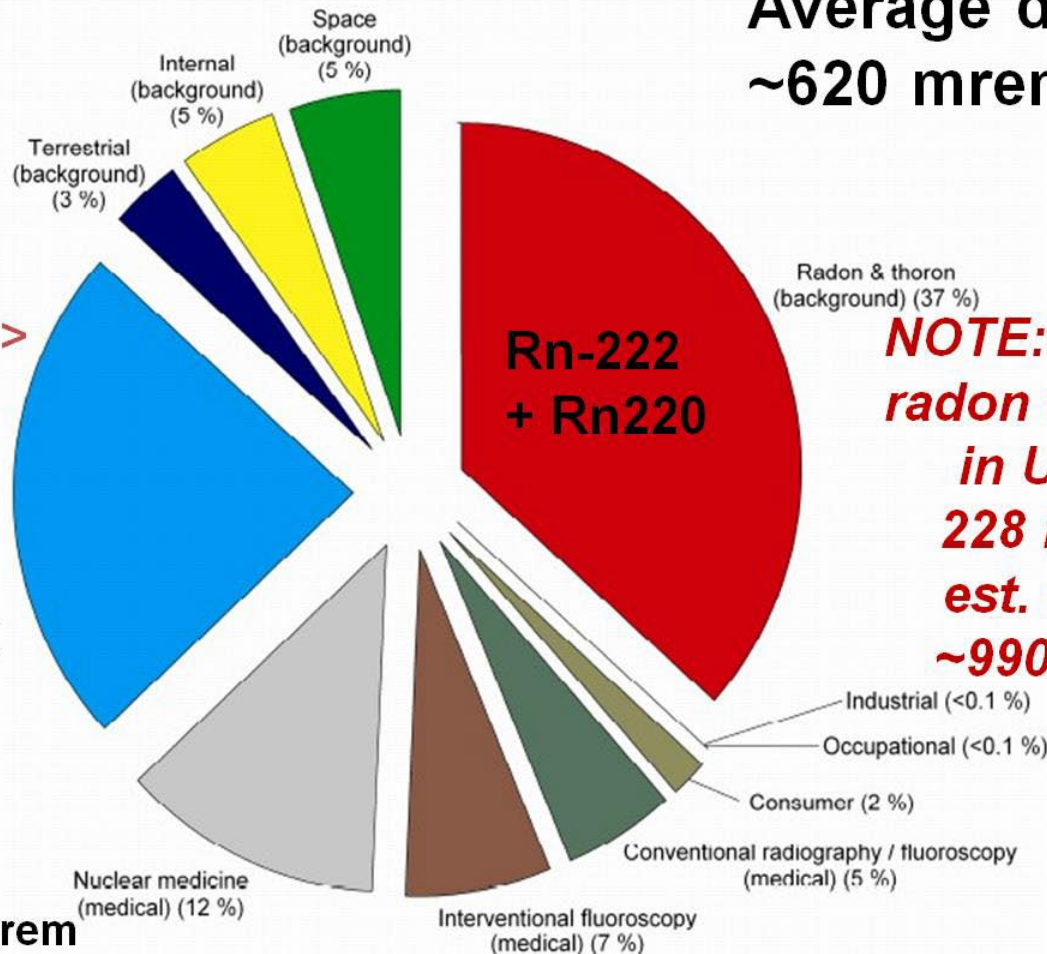
# Average Radiation Dose - USA



All Exposure Categories  
Collective Effective Dose (percent), 2006

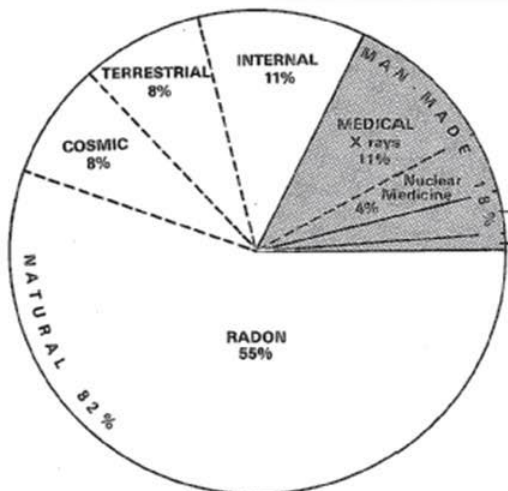
**NCRP Rpt. 160**

**Average dose  
~620 mrem/yr**



**NOTE: average radon eff. dose in USA is 228 mrem; est. for PA ~990 mrem**

**Medical Dose from CT >**



**^ 1986 Ave: ~360 mrem**

# Radiation Dose & Control Limits

Public 100 mrem/yr; 500 mrem/yr;

25 mrem/yr any one source; 4 mrem/yr drinking water

Worker 5,000 mrem/yr whole body

15,000 mrem/yr lens of eye

50,000 mrem/yr skin / extremity / organ

Worker's embryo / fetus 500 mrem; and less than

50 mrem/month

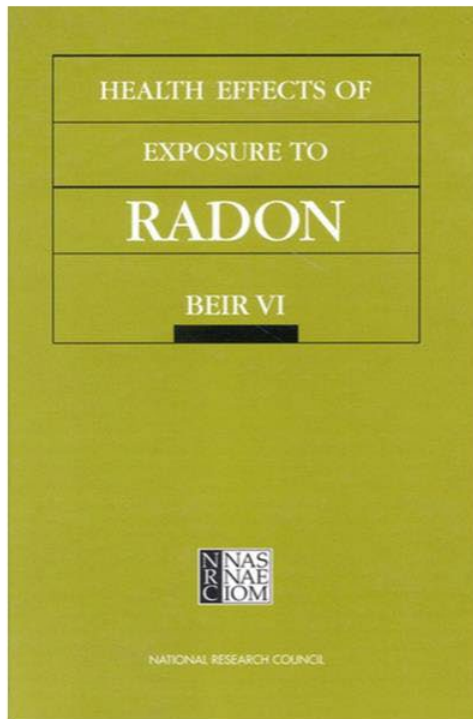
Patients few dose limits; 300 mrad mammography



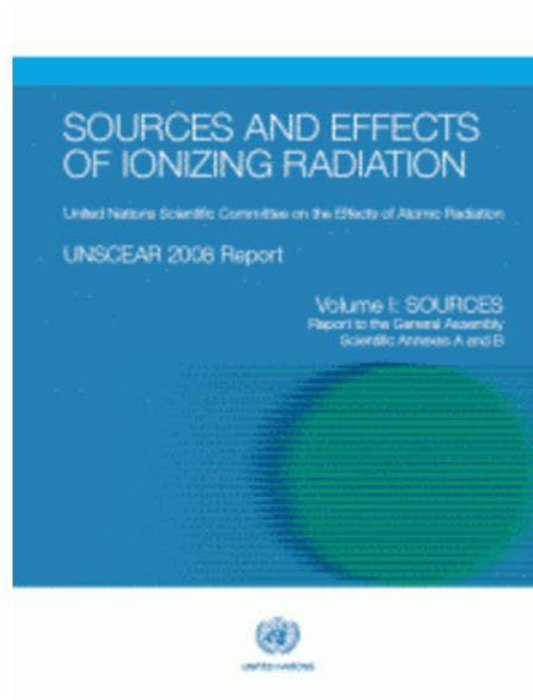
\*\*\* Radon\*\*\* 4 pCi/L home 'action level;' 30 pCi/L workers



# Radon Studies, Reports and FSs



**NAS - BEIR VI  
Report**



**UNSCEAR 2008  
Vol. 1, Annex B**

## EPIDEMIOLOGY

### Radon, Cigarette Smoke, and Lung Cancer: A Re-analysis of the Colorado Plateau Uranium Miners' Data

Suresh H. Moolgavkar,<sup>1</sup> E. Georg Luebeck,<sup>1</sup> Daniel Krewski,<sup>2</sup> and Jan M. Zielinski<sup>2</sup>

Much of our knowledge regarding the interaction of radon and tobacco smoke in the etiology of human lung cancer derives from studies of uranium miners. In this article, we present a re-analysis of lung cancer mortality in the Colorado Plateau miners' cohort within the framework of the two-mutation clonal expansion model of carcinogenesis. This analysis takes into account the patterns of exposure to radon and cigarette smoke experienced by individuals in the cohort. A simultaneous re-analysis of the British doctors' cohort indicated that those model parameters relating to the effects of tobacco were comparable in the two data sets. We found

no evidence of interaction between radon and tobacco smoke with respect to their joint effect on the first or second stage mutation rates or on the rate of proliferation of initiated cells. The age-specific relative risks associated with joint exposure to radon and cigarette smoke, however, were supra-additive but submultiplicative. The analysis also confirmed that fractionation of radon exposures leads to higher lung cancer risks. Finally, we present some estimates of lung cancer risk from environmental radon exposure for non-smokers and smokers. (Epidemiology 1993;4:204-217)

Keywords: initiation, interaction, multistage models, promotion, synergy.

### EXAMPLE

## Uranium Miner Studies

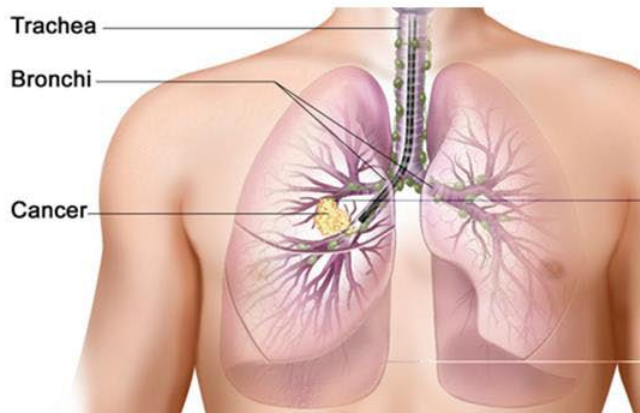
Many others by: EPA, ATSDR, CRCPD, HPS, ICRP, et al.

# Radiation & Radon Exposure

## Biological Effects

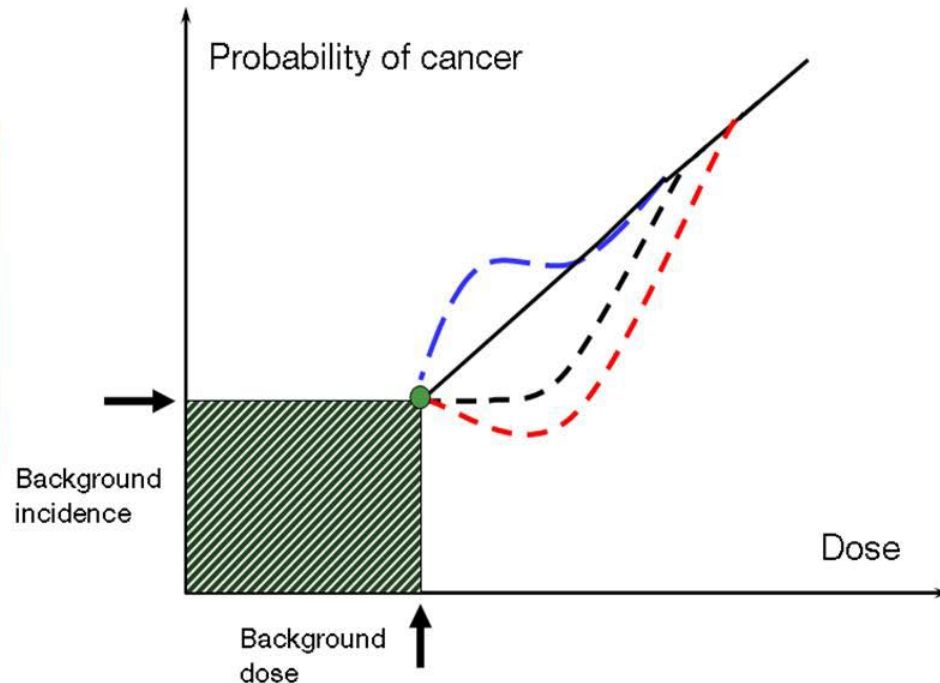
Cancer – assume a linear no threshold (LNT) model

**Radon is a lung cancer risk.**

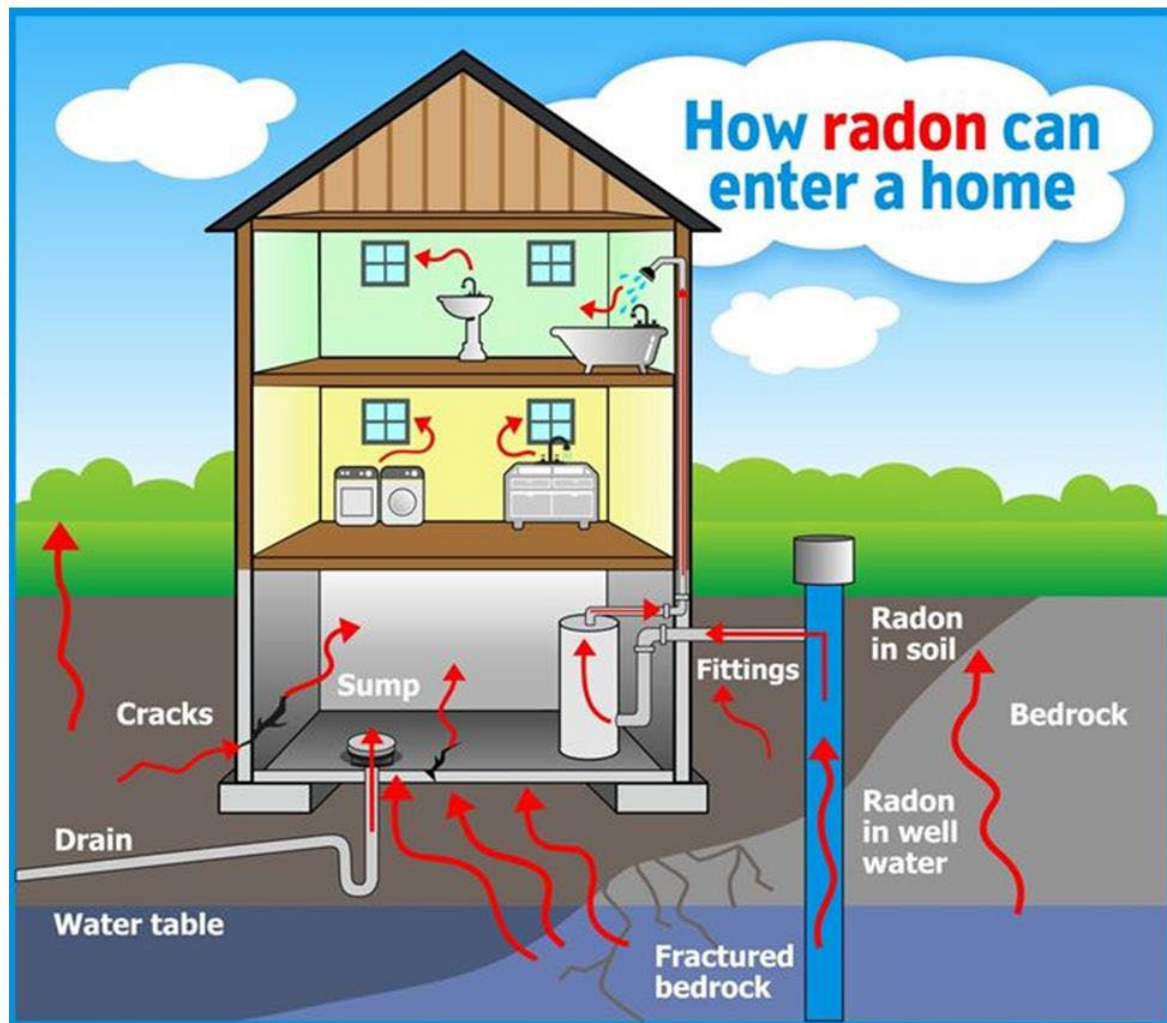


**EPA estimates ~21,000 lung cancers per year from radon; smokers have highest risk.**

Dose-Response Relationships



# Radon in Soil & Groundwater



In PA, the main route of entry for **radon** is from penetrations and cracks in the basement floor and walls.

Figure by PA DEP



# Radiation Control in USA

## In PA



**DEP: X rays,  
Accelerators,  
Radon, and  
Radioactive  
Materials &  
Emerg. Prep.**



# BRP - Mission

**BUREAU OF RADIATION PROTECTION**  
*"Building on the past to shape the future."*

## **MISSION**

**"Our mission is to safeguard the public health and safety and the environment from harmful and unwanted, unnecessary or inappropriate exposure from controllable radiation sources."**

We "LEAD BY EXAMPLE" and value:

- Public Service
- Teamwork
- Professional Development
- Open Communication
- Effective Radiation Protection

**Radon is a  
controllable  
radiation  
source!**

# PaDEP - BRP

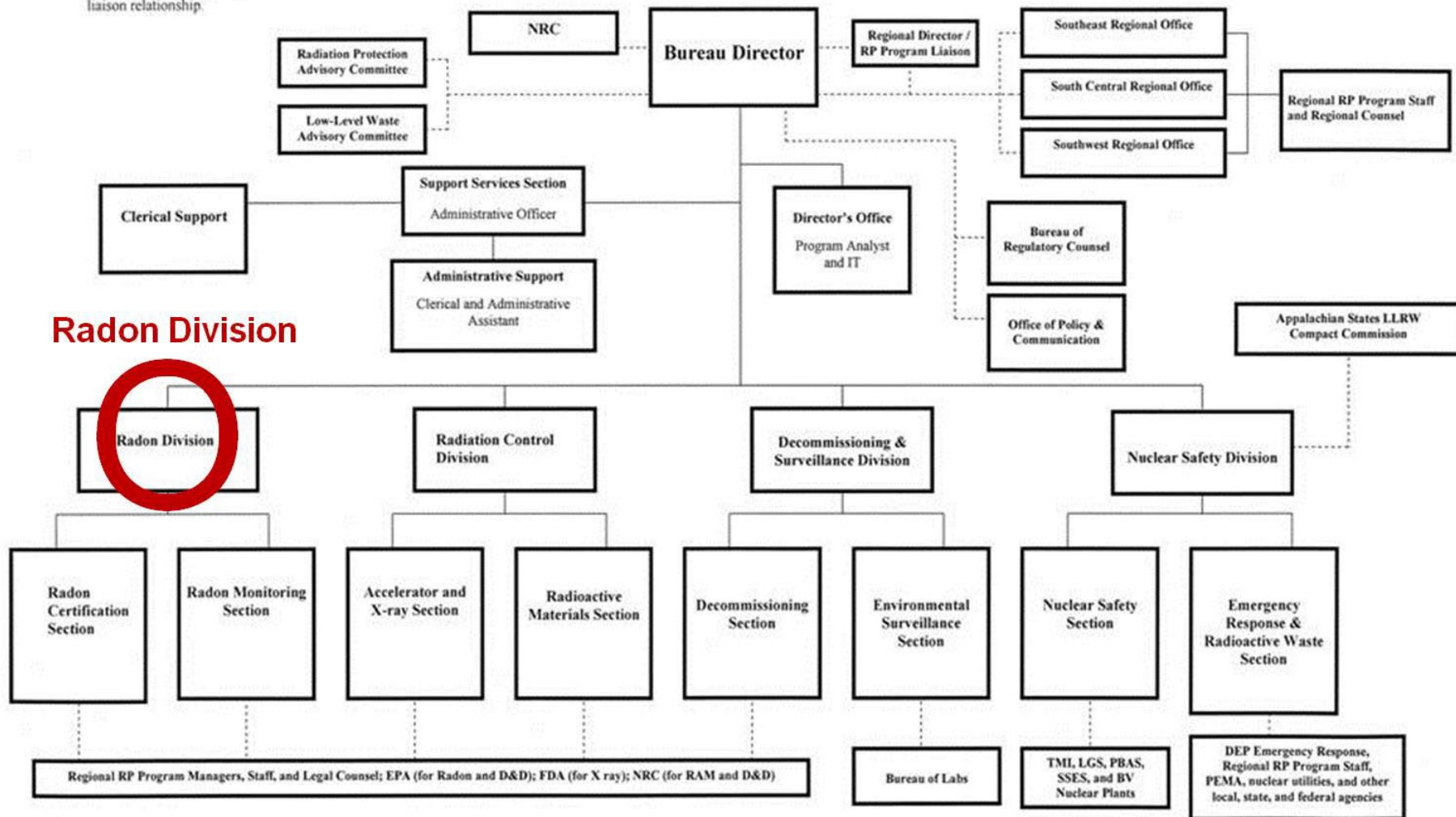
## PA Rad. Protection Program Scope

- 9 Power reactors, EP/ER, Env. Surveillance, Nuclear Safety
- 1 Research reactors at PSU, EP/ER
- 1 Navy / DOE facility; Bettis Atomic Lab; EP/ER
- 2 Uranium tailings cells, several radium site clean-ups
- Several old rare earth processors with U / Th slag
- NRC AS w/ ~950 RAM licensees; ~ 10 complex D&D sites
- **760 Certified radon testers, labs and mitigators**
- 250 Accelerators (medical and industrial)
- 30,000 X-ray units in 11,000 facilities
- 380 FDA mammography units
- 170 Solid waste facilities monitoring for radiation; ER
- Many metal recyclers monitoring for radiation; ER
- Major transportation routes carrying RAM & SNF; EP/ER

# PA DEP - BRP

## BUREAU RADIATION PROTECTION

NOTE: A dotted line ..... represents a major matrix liaison relationship.



# Legislative Authority

- **Radiation Protection Act (Act 1984-147)**
- **Solid Waste Management Act (Act 1980-97)**
- **Appalachian States LLRW Compact Act (Act 1985-120)**
- **LLRW Disposal Act (Act 1988-12)**
- **LLRW Disposal Regional Facility Act (Act 1990-107)**
- **Radon Certification Act (Act 1987-43)**



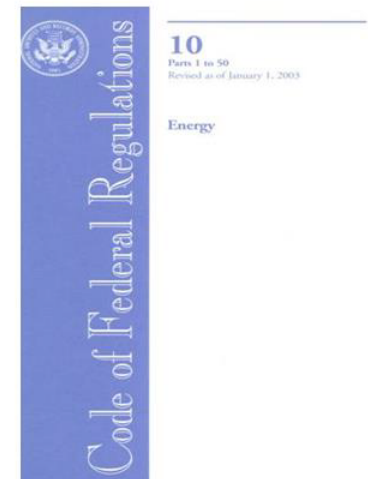
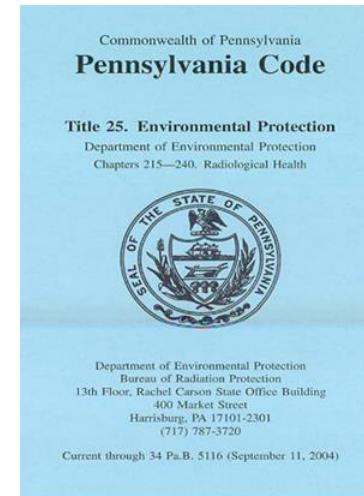
# PA RP Regulations

## PA Code: Title 25 Environmental Protection

### > Article V. Radiological Health\*

- 215. General Provisions
- 217. Lic. of Radioactive Materials (RAM)
- 219. Standards for Protection Against Rad.
- 220. Notice, Instructions & Reports ....
- 221. X-rays in the Healing Arts
- 230. Packaging & Transport of RAM
- 236. LLRW Management & Disposal
- **240. Radon Certification**

\*Note: Partial list of Chapters; and in Nov. 2001 PA incorporated NRC regs in Title 10 CFR by reference



# Natural Uranium & Radon

## Uranium-238 Decay Chain

U-238~98% by wt, ~50% of radioactivity  
*Radionuclide (half-life)*

### Explanation

↓ Alpha decay  
 ↗ Beta decay

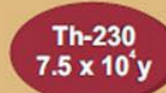
Uranium



Protactinium



Thorium



Radium



Radon

>



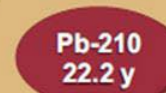
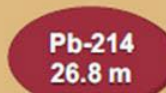
Polonium



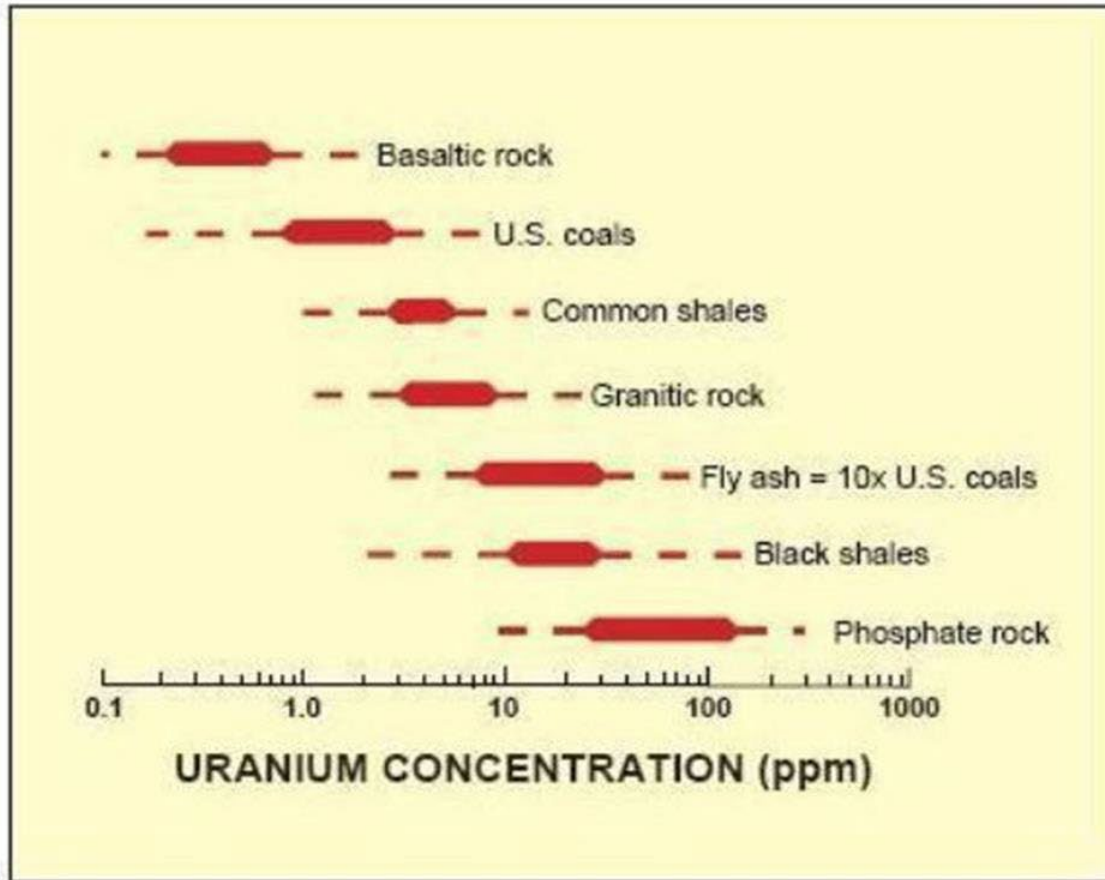
Bismuth



Lead



# Uranium Concentrations



Typical range of uranium concentration in coal, fly ash, and a variety of common rocks.

c1978 C. PA  
Radon Study  
by PP&L.

BRP was  
preparing to  
do follow-up  
work, then we  
got busy...



Figure 1. Graph from Radioactive Elements in Coal and Fly Ash: Abundance, Forms, and Environmental Significance. U.S. Geological Survey Fact Sheet FS-163-97. October, 1997



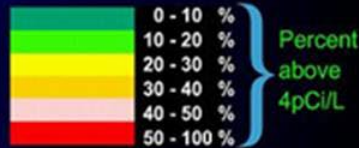
# Dec. 1984 - the "Index House"

LGS employee's house in Boyertown, PA caused radiation alarms at this NPP.



## Zip Code map of Pennsylvania

This map of Pennsylvania shows the % of known test results that exceed EPA's action guideline of 4.0 picocuries per liter. It is estimated that over 40% of the homes in Pennsylvania exceed the EPA's action guideline.



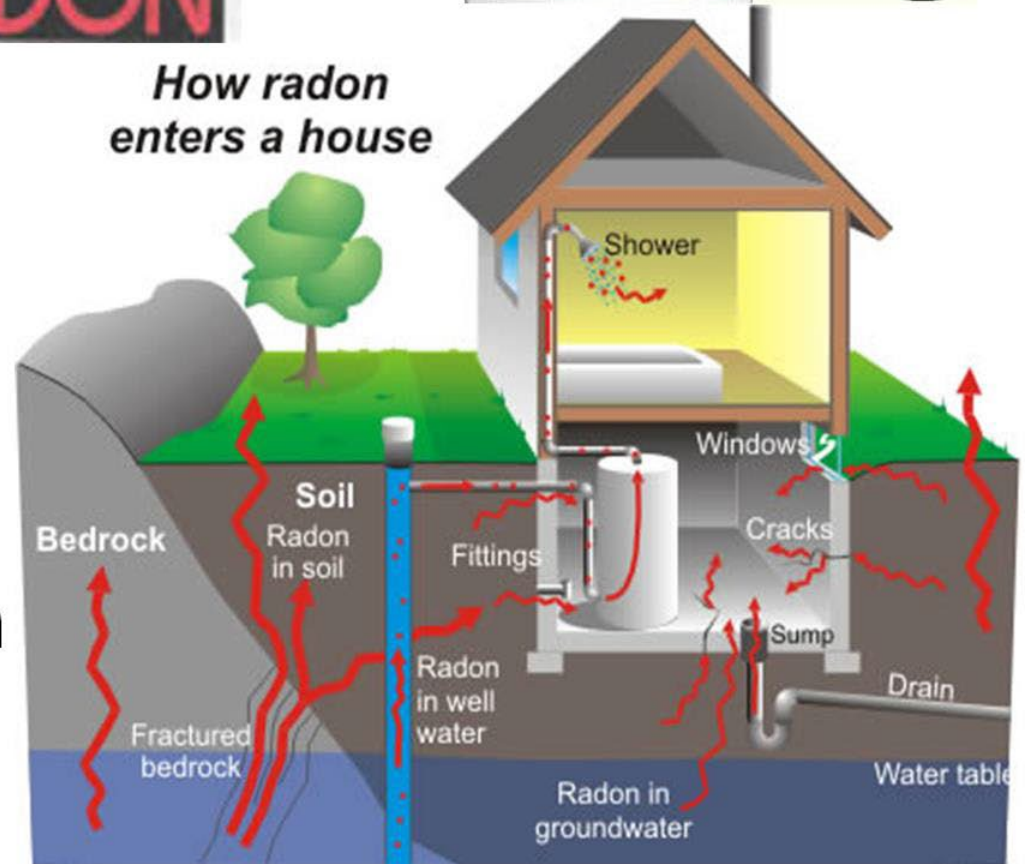


# Radon-222

- EPA's c1988 indoor radon 'action level' set at 4 picocuries per liter (4 pCi/L)
- Versus the 1984 "Index House" with 2,600 pCi/L!!

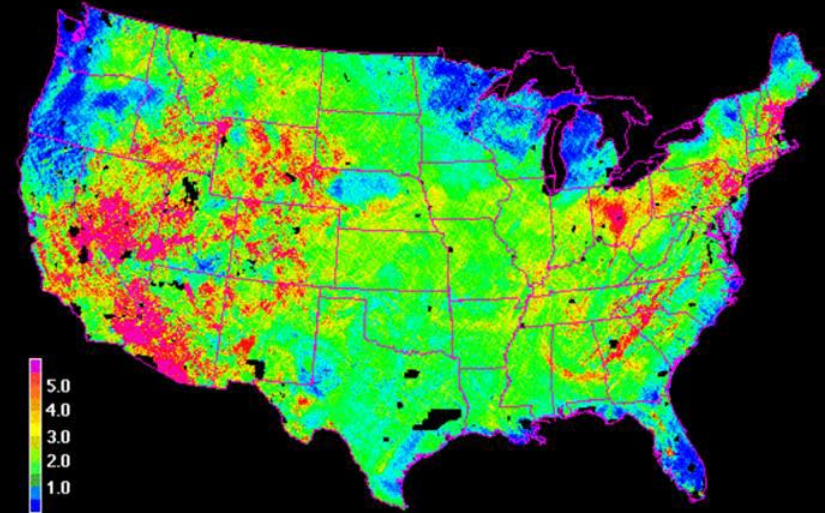
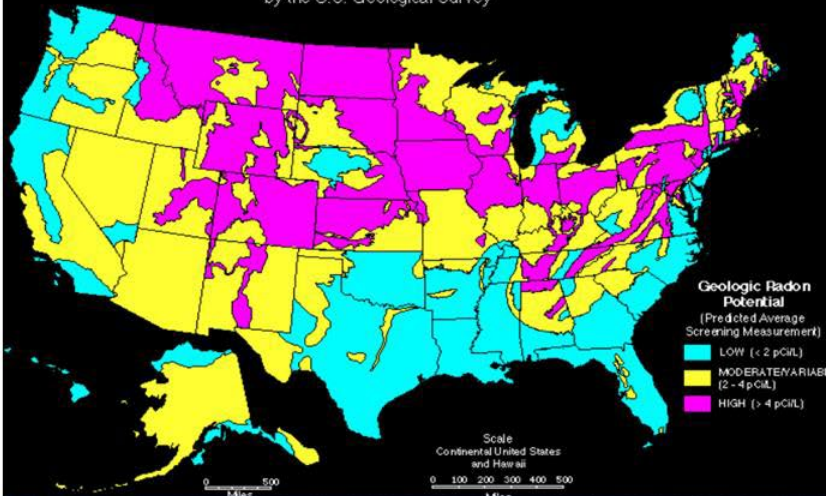


How radon enters a house

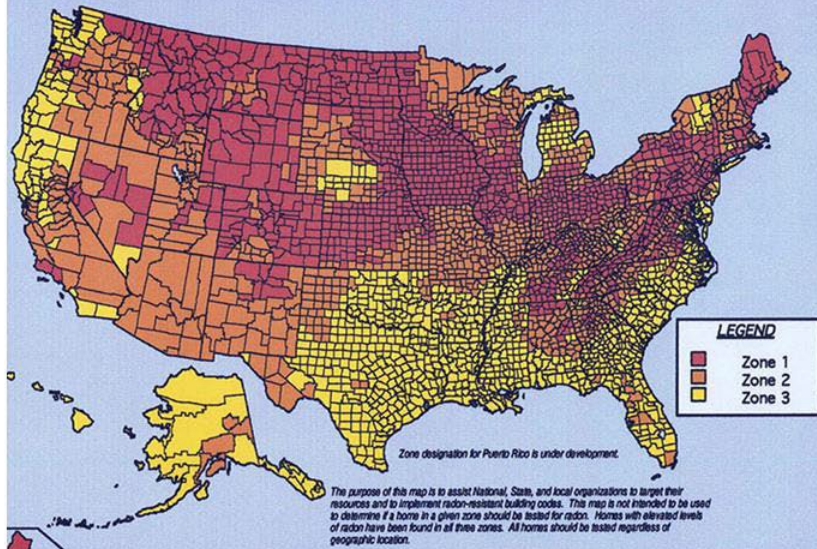


# EPA & USGS Maps - note PA

GENERALIZED GEOLOGIC RADON POTENTIAL OF THE UNITED STATES  
by the U.S. Geological Survey

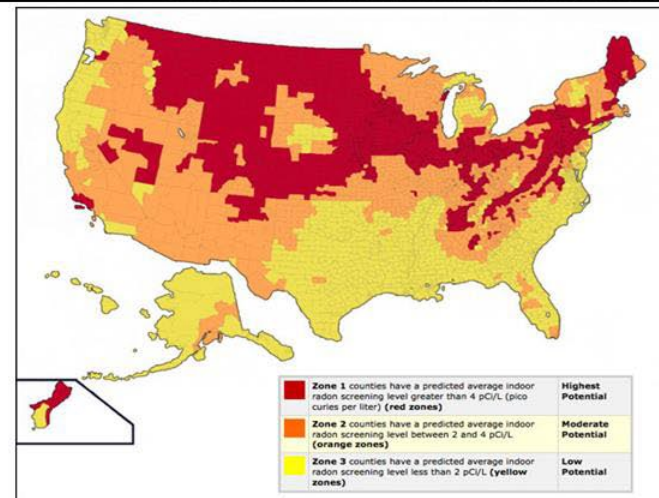


EPA Map of Radon Zones



Uranium Concentrations

Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993

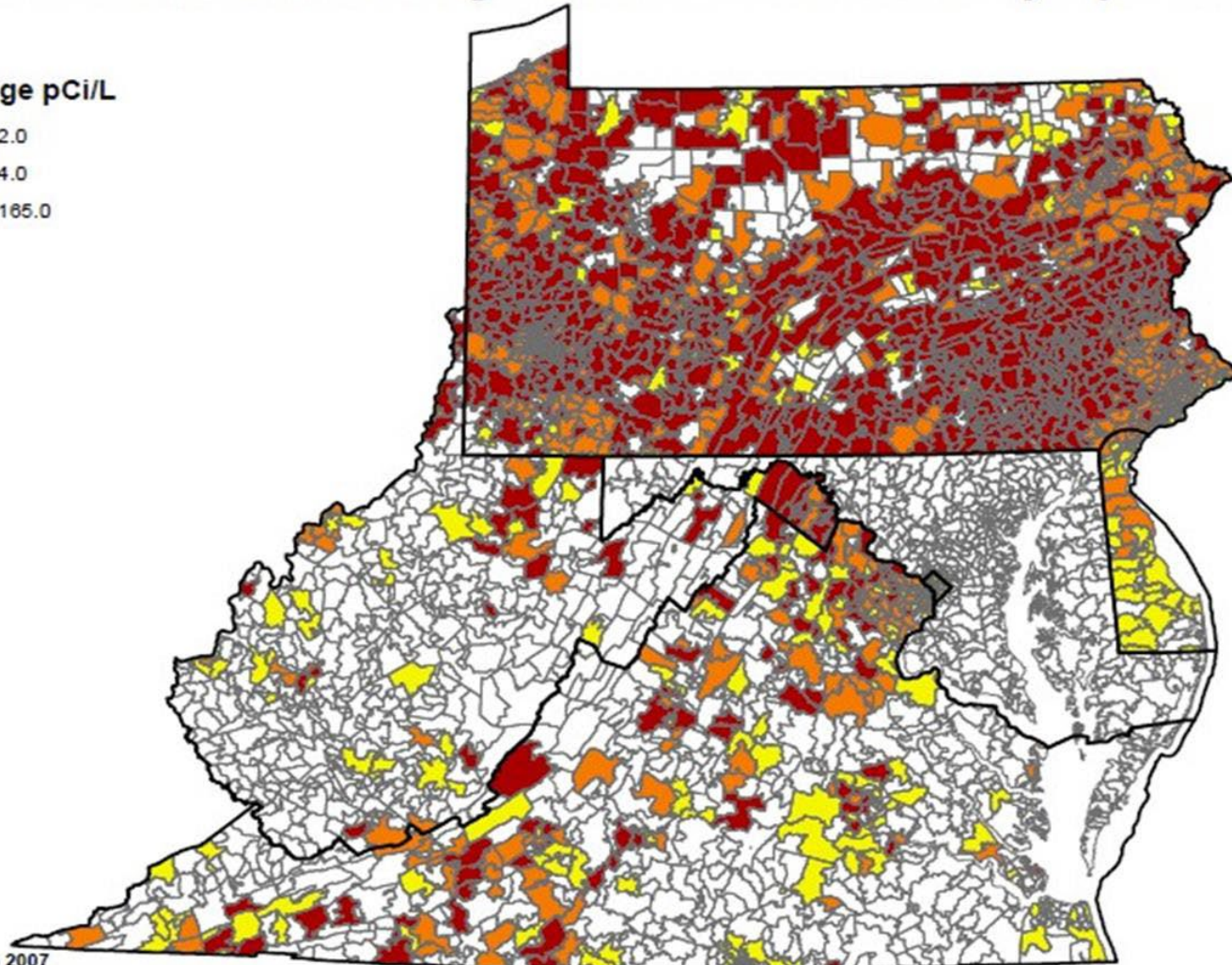




# EPA Region 3 Map - note PA

## EPA Region III: 2005-2009 Average Radon Measurements By Zip Code

Radon, Average pCi/L



\* WV data current to 2007  
\* DC, DE, PA, VA current to 2009  
\* No data available for MD



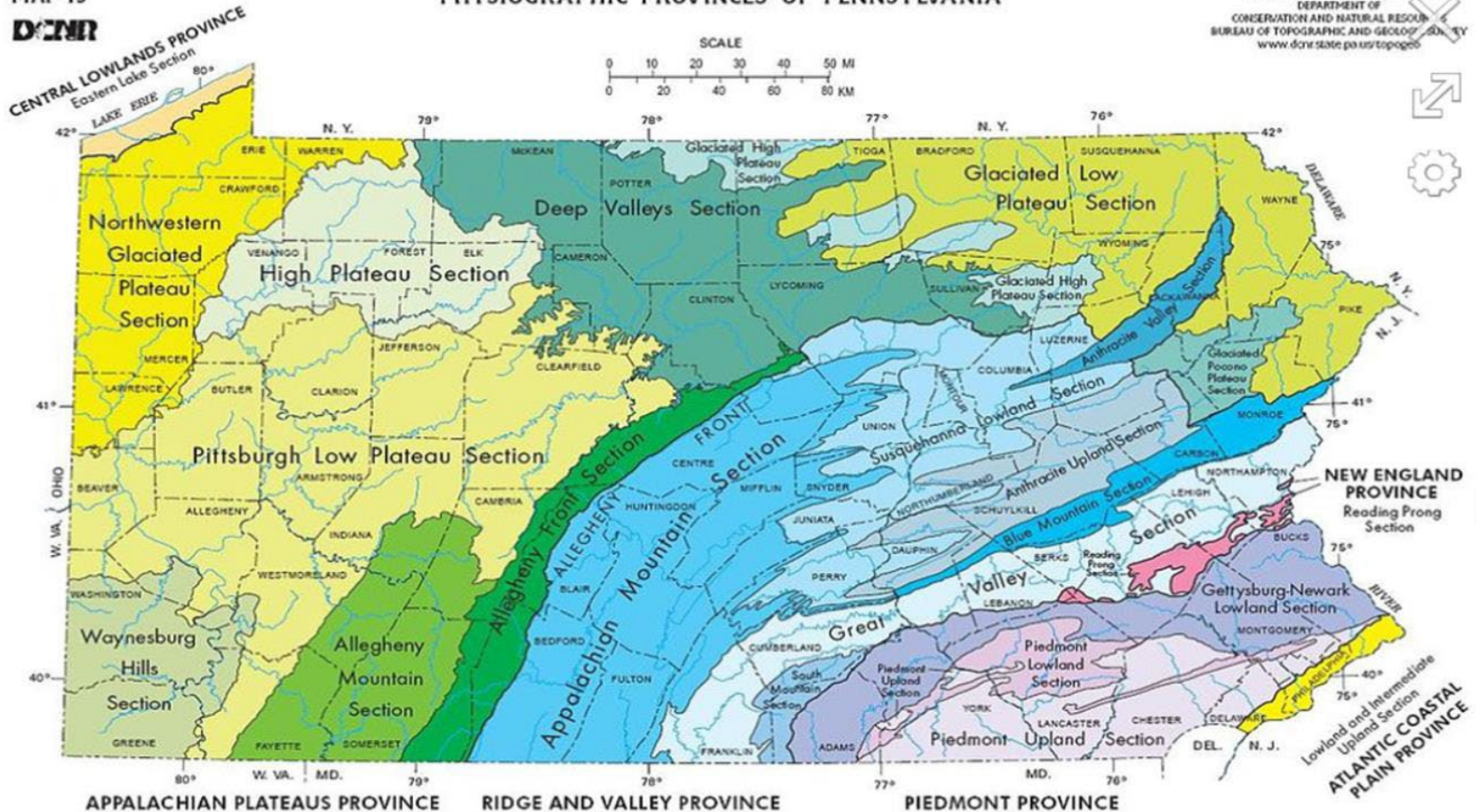
# High Radon in Reading Prong

MAP 13



## PHYSIOGRAPHIC PROVINCES OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA  
DEPARTMENT OF  
CONSERVATION AND NATURAL RESOURCES  
BUREAU OF TOPOGRAPHIC AND GEOLOGICAL SURVEY  
www.dcnr.state.pa.us/topog



CENTRAL LOWLANDS PROVINCE



APPALACHIAN PLATEAUS PROVINCE



EXPLANATION

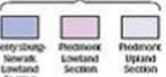
RIDGE AND VALLEY PROVINCE



NEW ENGLAND PROVINCE



PIEDMONT PROVINCE



ATLANTIC COASTAL PLAIN PROVINCE



SYMBOLS



> The location of the Reading Prong is shown in dark pink.



# Reading Prong (PA Geology – Spring 2014)

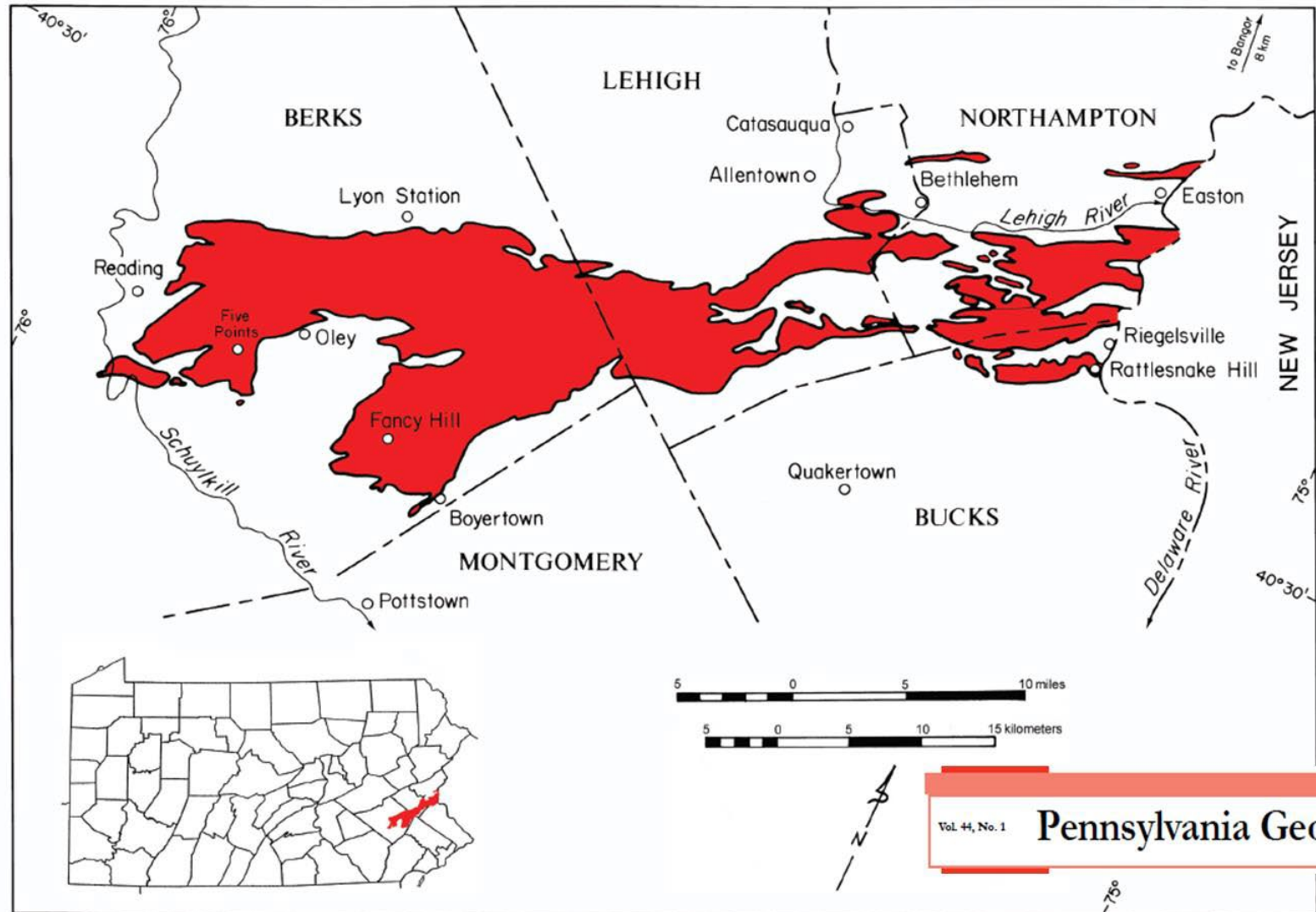
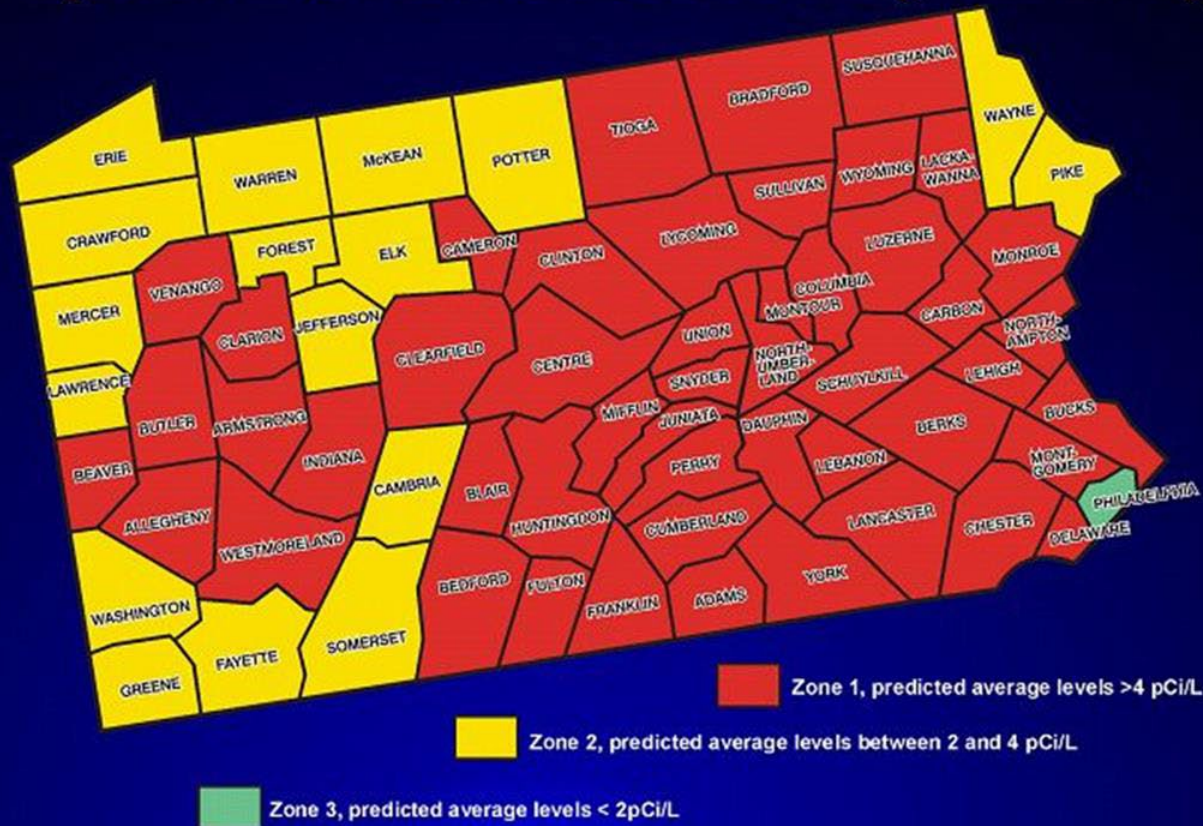


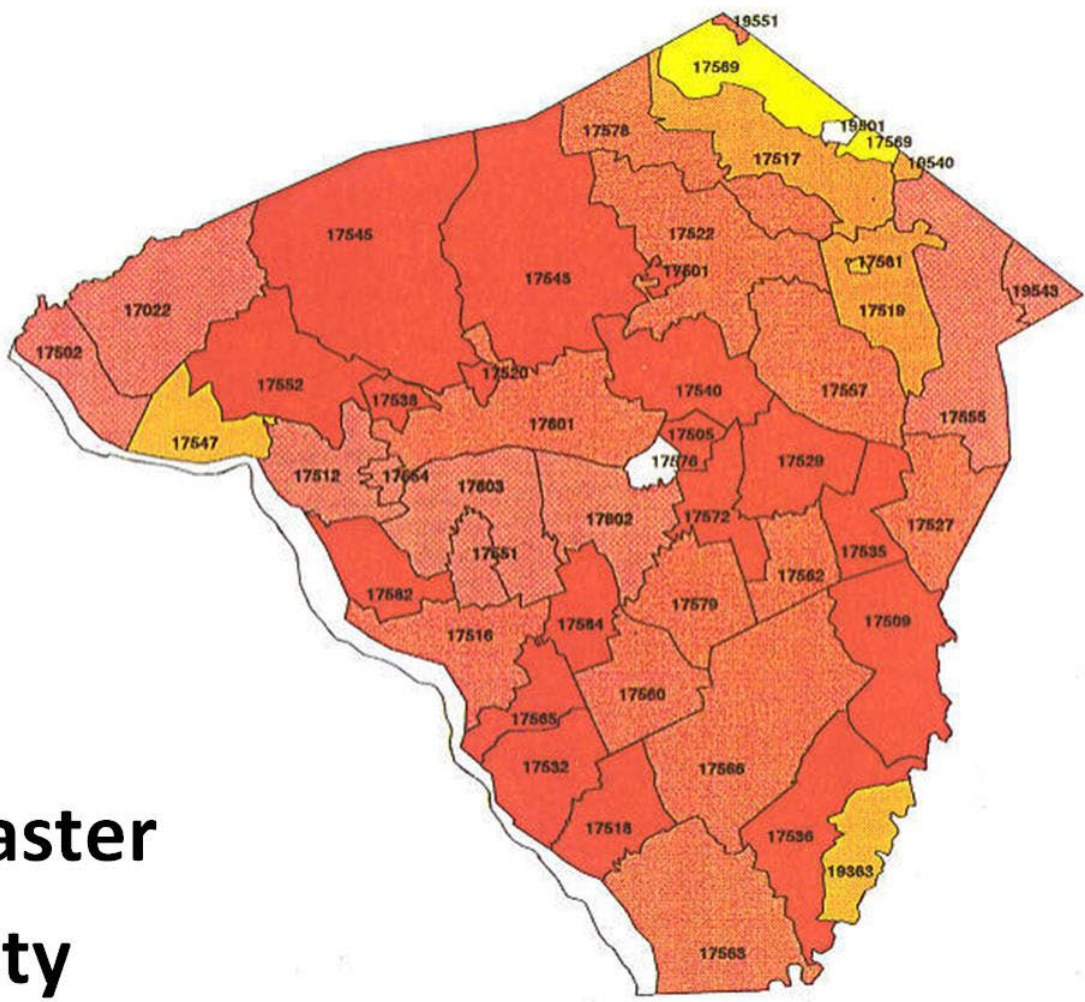
Figure 1. Map showing the extent and location of the Reading Prong in eastern Pennsylvania.

# EPA - Radon Zones in PA











## Pennsylvania Radon Zones by County



# Radon Testing



Percentage of homes above 4.0 pCi/L

-  No data
-  10%
-  20%
-  30%
-  40%
-  50%
-  60%
-  70%
-  80%
-  90%

Lancaster County



# PA Radon Program

- **Radon Certification Act required development of regulations**
- **Regs in PA Title 25, Article V, Chapter 240**
- **PA certifies all radon testers, mitigators and laboratories**
- **Thru an EPA 'SIRG' grant Radon Division does education and outreach to promote testing and 'radon resistant new construction'**

# PA Radon Program (cont.)

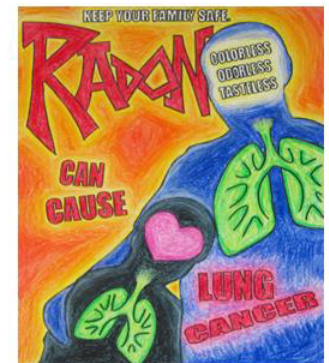
## **Radon education and outreach includes:**

- **Awareness thru TV & Radio PSAs and print ads**
- **Maintaining an 800 telephone number**
- **Trained staff to provide Rn test and mitigation assistance**
- **Frees test kits thru 'Newborn' program**
- **Training for educators, builders and real estate agents**
- **Work with PA Departments of Health and Education**

# PA Radon Program (cont.)

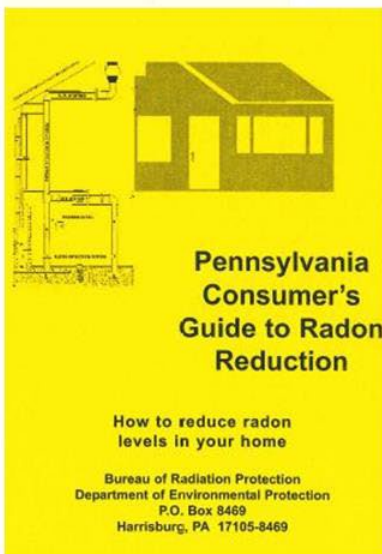
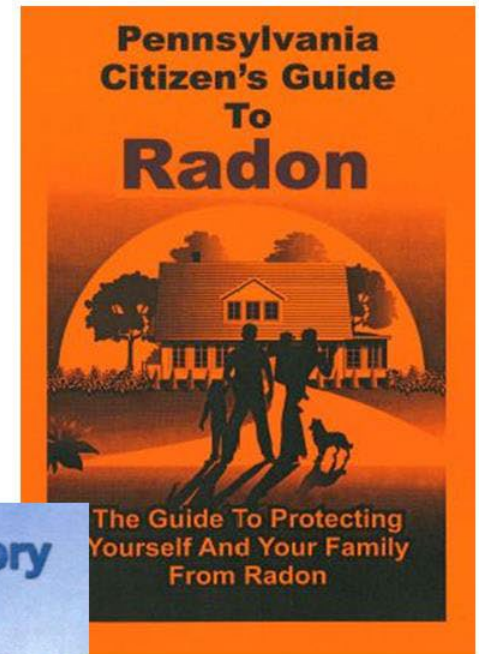
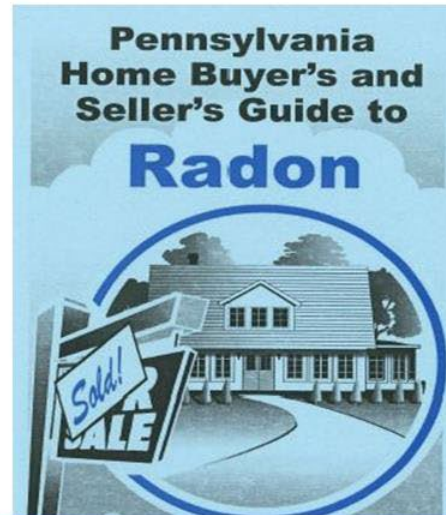
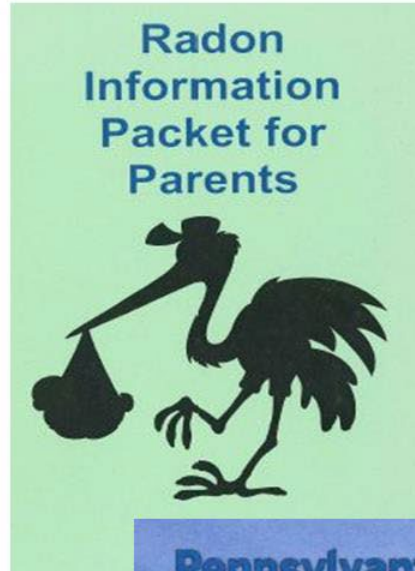
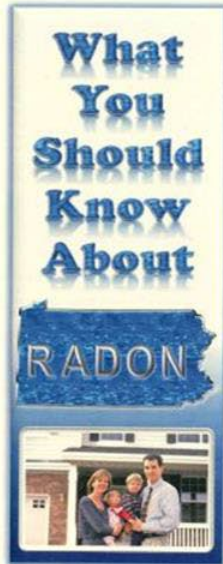
## Radon education and outreach includes:

- Regular calls and meetings with EPA and other states
- Special studies (e.g., data trends, 'hot spot' surveys, blind testing, moisture mitigation, etc.)
- Assistance for hard to mitigate home
- Frees test kits thru American Lung Association
- School science project support and Radon Calendar contest
- Develop radon educational materials





# PA Radon Educational Materials



**Pennsylvania Radon Services Directory**

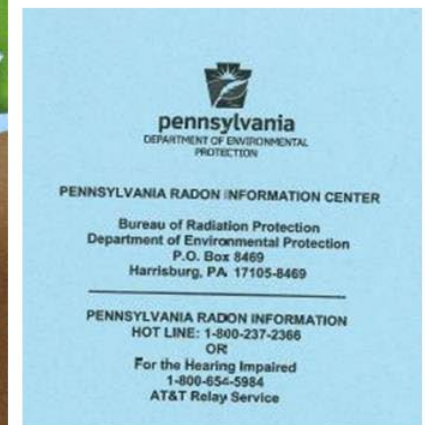
Pennsylvania law requires that anyone performing radon services (testing, mitigation, and/or laboratory analysis) be certified by the Department of Environmental Protection (DEP)

Use your smartphone to scan this code to access DEP's Pennsylvania Radon Services Directory, an online list of individuals and firms that are certified to perform testing and mitigation services in Pennsylvania.

Testing the radon level in your home is inexpensive and easy. Test kits are available at many home improvement stores for under \$15.

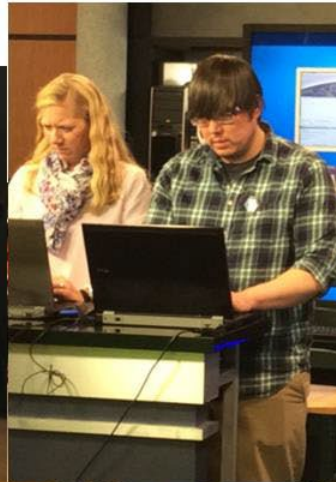
For questions about radon certification or testing, contact DEP's Bureau of Radiation Protection at 800-23-RADON.

The cover has a blue and white background. It features a stylized illustration of a house with four yellow arrows pointing upwards from the ground towards the house, symbolizing radon gas entering the home.





# TV Radon Phone-a-thons



# Radon Test Devices



Pylon CRM



E-PERMs



Charcoal Detectors

Short-term, or  
Long-term

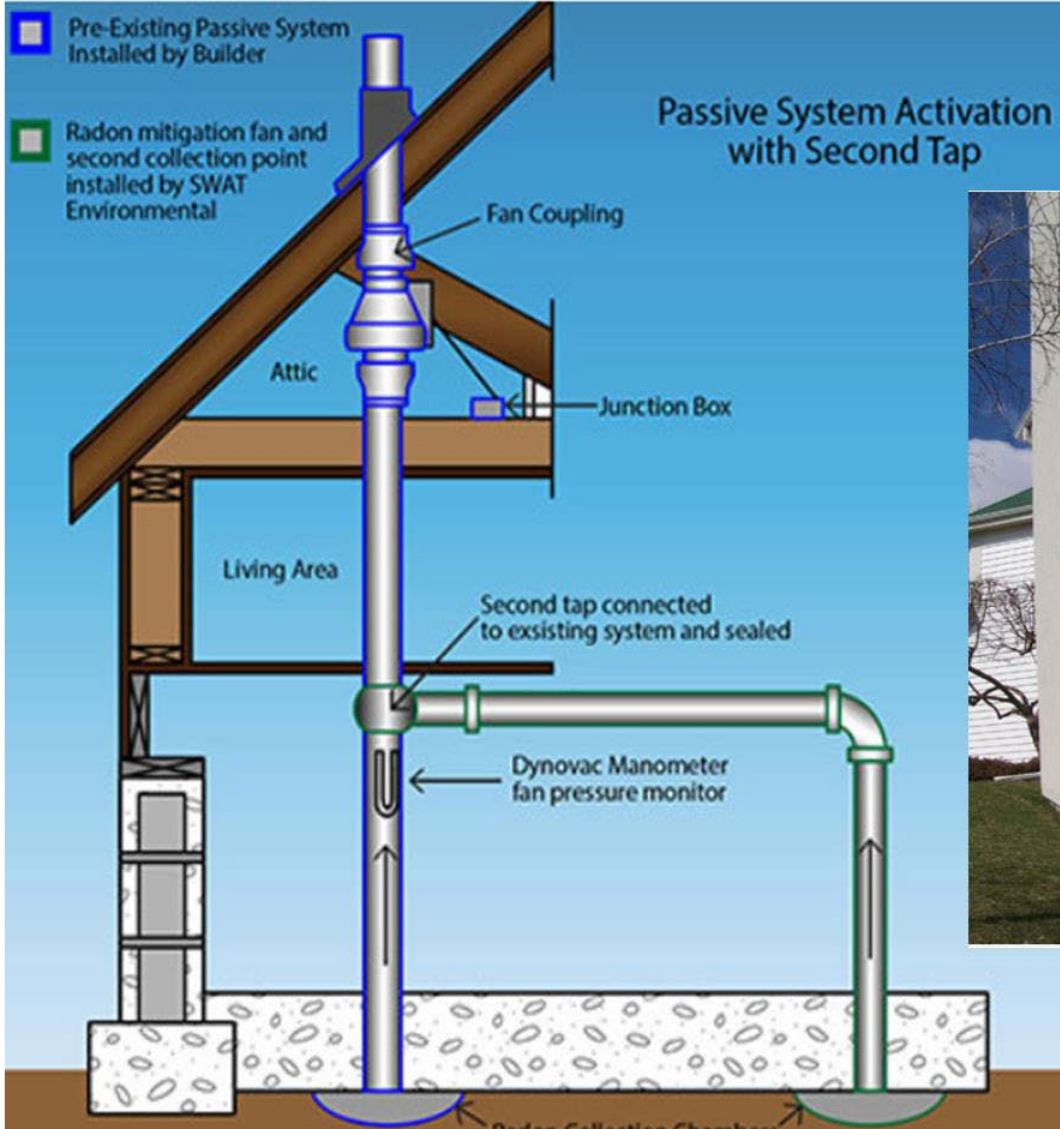


Radtrak ATD





# Radon Mitigation



## Sub-slab Depressurization

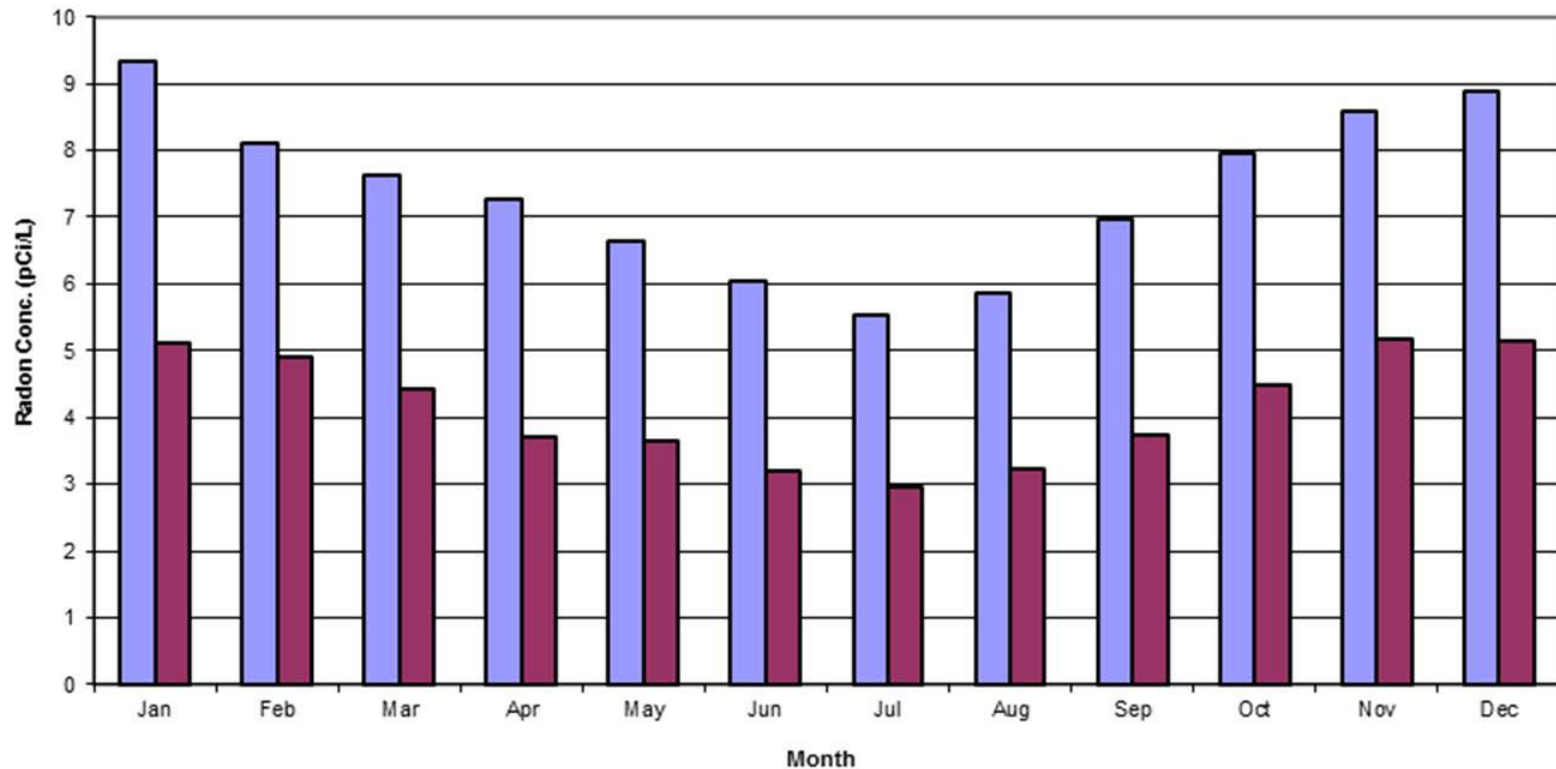


# PA Radon Database

## Residential Data, Basement ; Grouped by Season

Season	Sample Size	Average (pCi/L)
Jan, Feb, Mar	172,600	7.56
Apr, May, Jun	187,051	5.95
Jul, Aug, Sep	161,189	5.45
Oct, Nov, Dec	162,965	7.72

# PA Radon Database



 **< 1<sup>st</sup> Floor; ave. ~3.5 pCi/L**

 **< Basement; ave. ~7 pCi/L**



# PA Radon Database Use

**USGS Analysis**



Scientific Investigations Report 2013-5143

USGS Home  
Contact USGS  
Search USGS

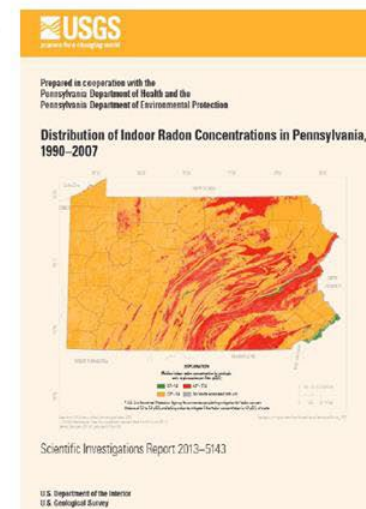
## ***Distribution of Indoor Radon Concentrations in Pennsylvania, 1990–2007***

Prepared in cooperation with the Pennsylvania Department of Health and the Pennsylvania Department of Environmental Protection

By Eliza L. Gross

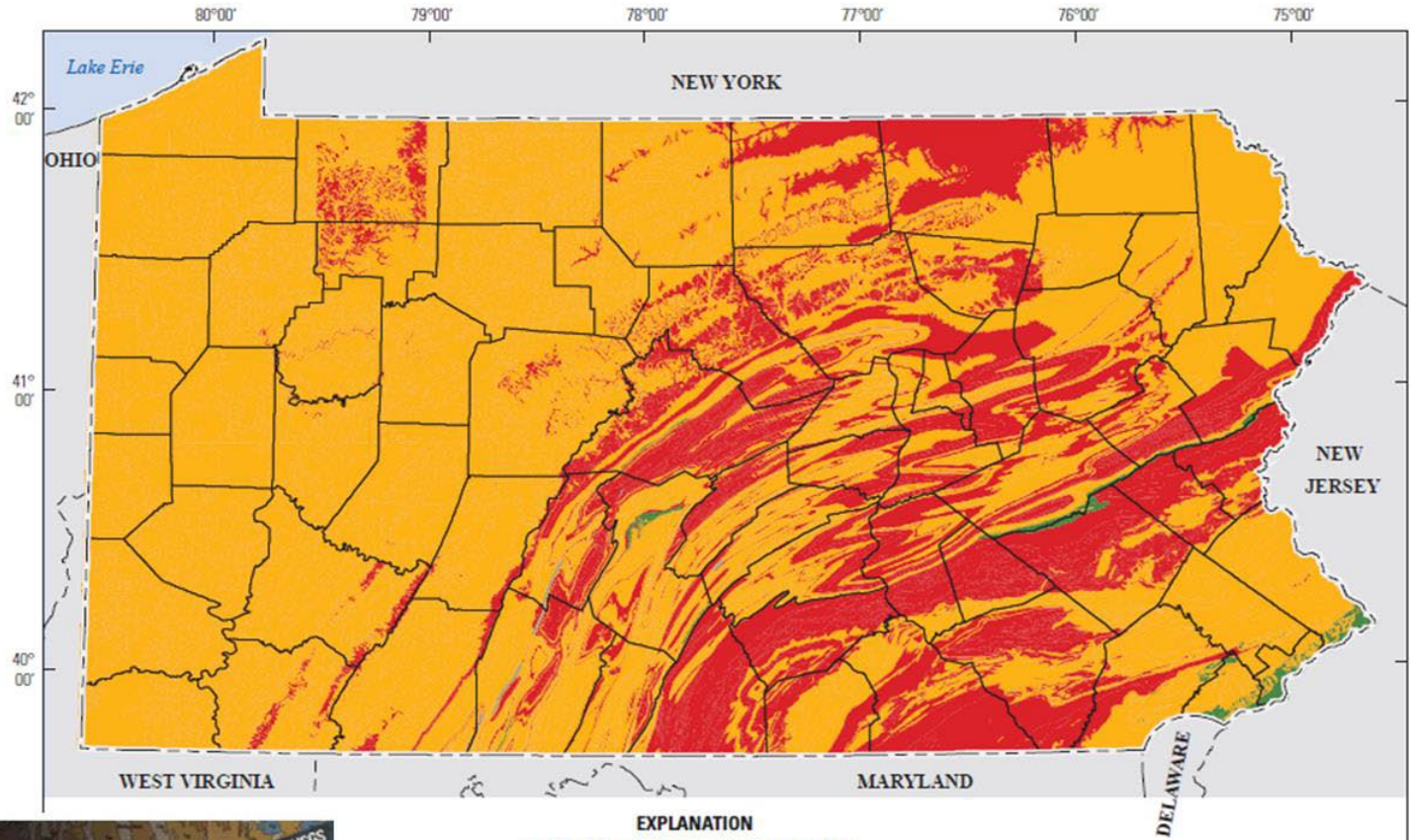
### **Abstract**

Results from 548,507 indoor radon tests from a database compiled by the Pennsylvania Department of Environmental Protection, Bureau of Radiation Protection, Radon Division, are evaluated in this report in an effort to determine areas where concentrations of radon are highest. Indoor radon concentrations were aggregated according to geologic unit and hydrogeologic setting for spatial analysis. Indoor radon concentrations greater than or equal to the U.S. Environmental Protection Agency (USEPA) action level of 4 picocuries per liter (pCi/L) were observed for 39 percent of the test results; the highest concentration was 1,866.4 pCi/L.



# PA Radon Database Use

## USGS Analysis



**EXPLANATION**  
Median indoor radon concentration by geologic unit, in picocuries per liter (pCi/L)

- 0.7 - 1.9
- 2.0\* - 3.9
- 4.0\* - 57.9
- No results associated with unit



\* U.S. Environmental Protection Agency recommends considering mitigation for radon concentrations of 2.0 to 3.9 pCi/L and taking action to mitigate if the radon concentration is 4.0 pCi/L or more.

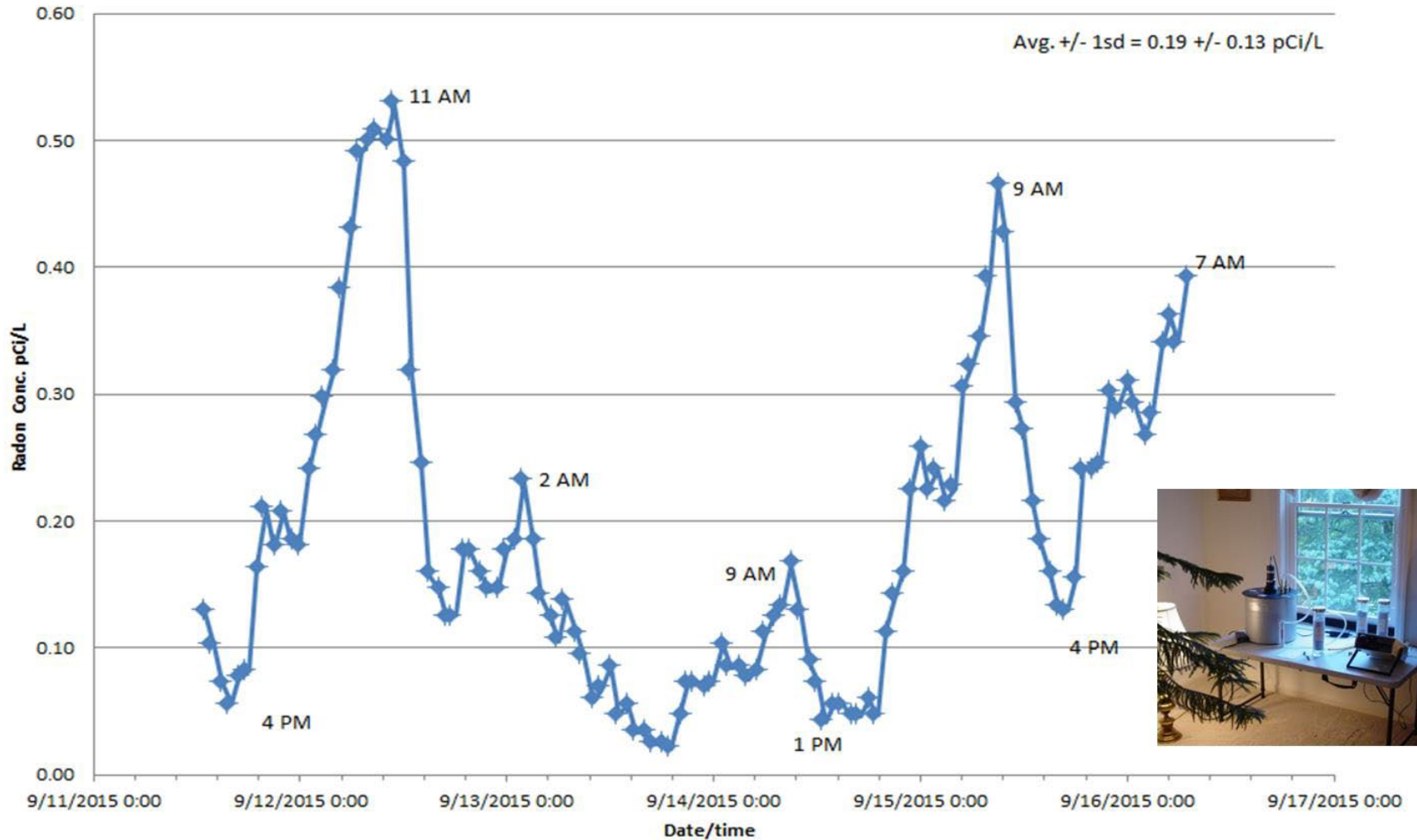
Base from U.S. Bureau of the Census digital data, 2000  
1:100,000 Albers Equal-Area Conic projection: Standard Parallels 40° N and 42° N,  
Central Meridian -78° W, Latitude of Origin 39°

Geologic unit digital data from Pennsylvania Geological Survey, 2001



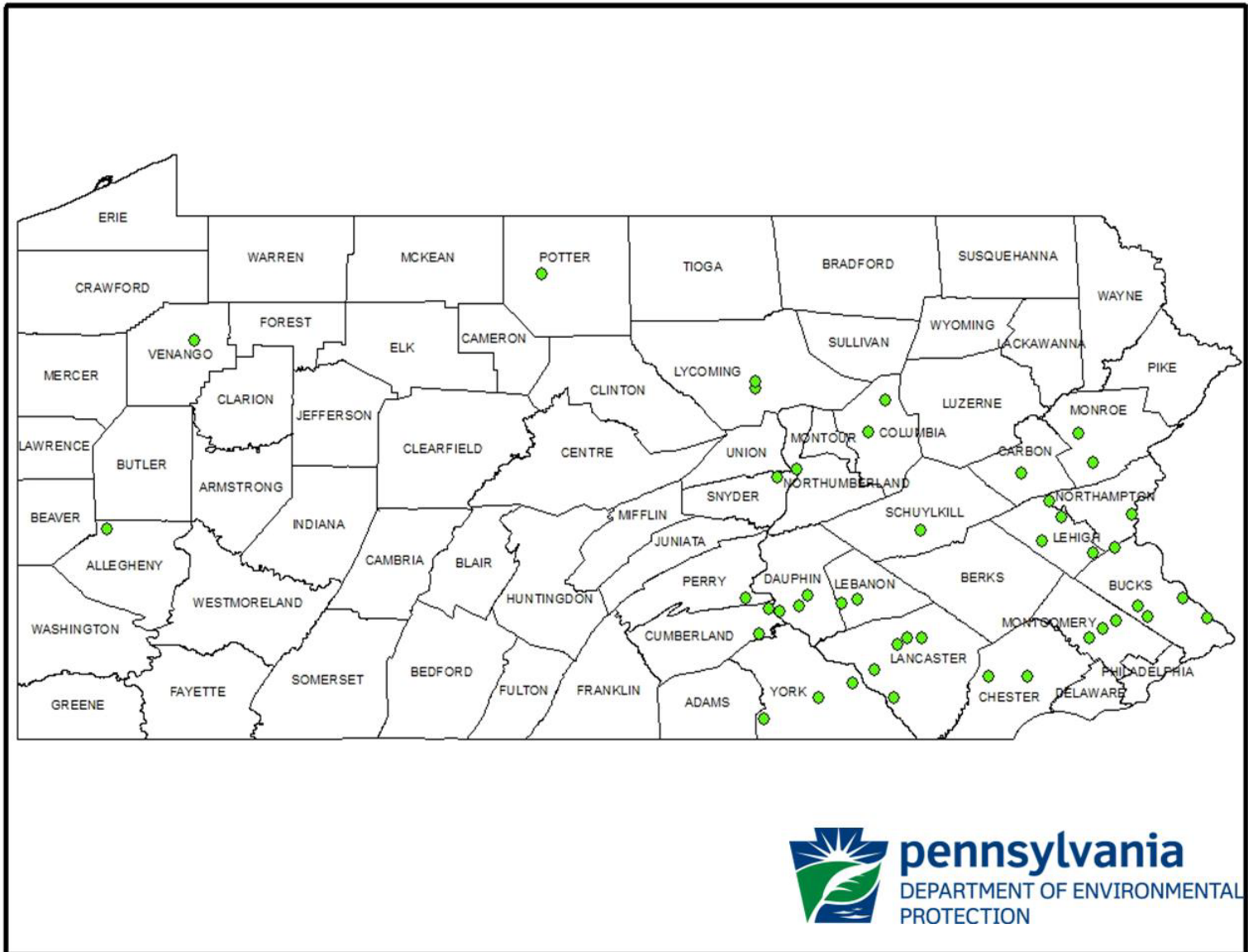
# Current Radon Study

## Ambient Radon Elizabethtown, PA





# Greater than 100 pCi/L Potential Hot Spot Survery Areas



# Discovery of a Very High Radon Area

- Mitigator informs DEP of home  $> 1,000$  pCi/L in early October 2014
- Radon Division does a targeted 'hot spot' survey mailing to over 500 homes
- Begin to see homes with **100s to 1,000s of pCi/L**
- Mid-November one home over **2,700 pCi/L** and in early December one with over **3,700 pCi/L !!!**





# Discovery of a Very High Radon Area





# Upper Saucon Twp Survey

	Count	Percentage
0 - 4 pCi/L	131	49.4 %
4 - 20 pCi/L	76	28.7%
20 - 100 pCi/L	26	9.8 %
100 - 999 pCi/L	18	6.8 %
> 1,000 pCi/L	14	5.3 %

~50% of these results are over 4 pCi/L.

Typically, only 40% of results in PA are over 4 pCi/L

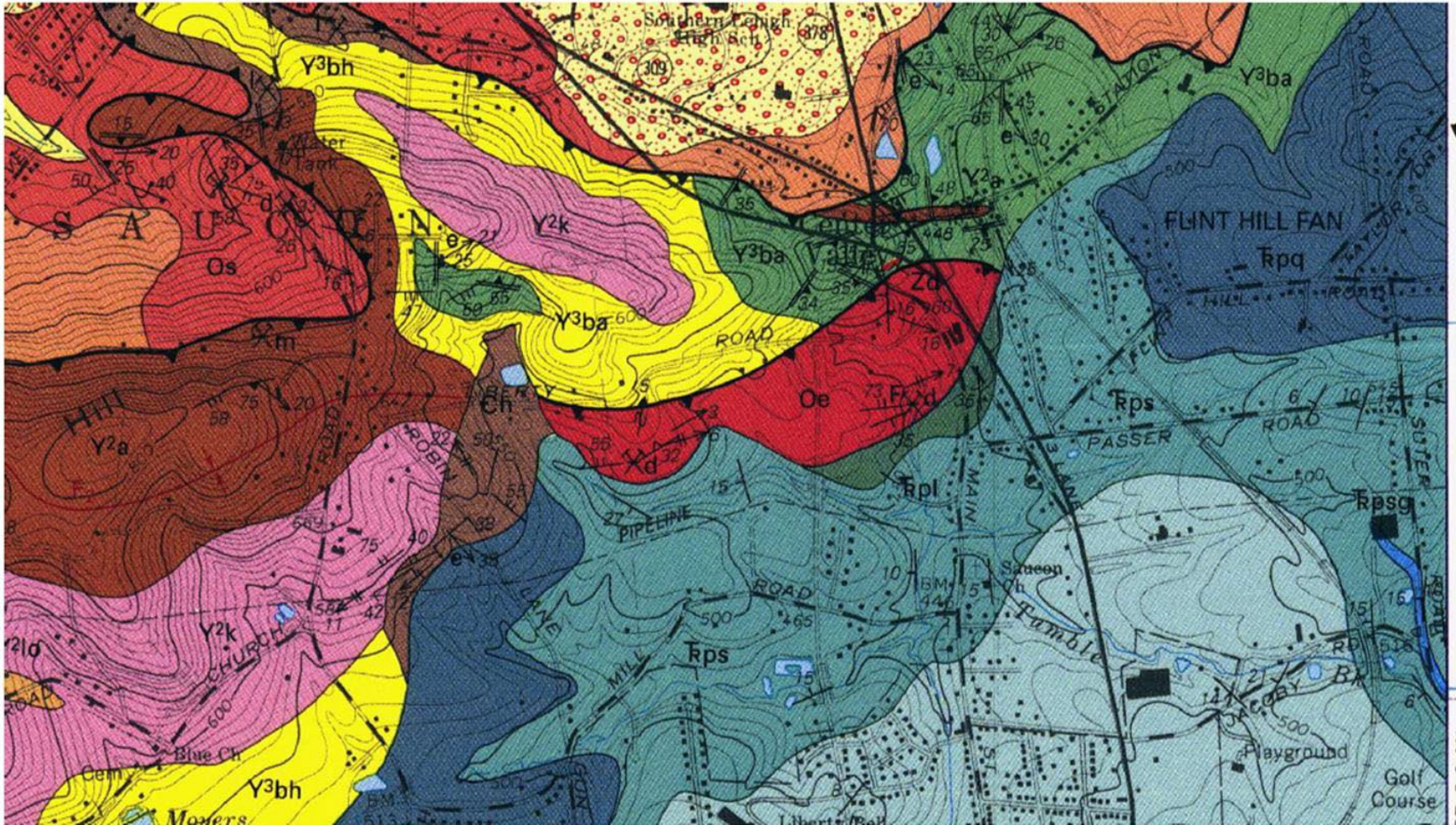
# Radon Levels Over 1,000 pCi/L

- **Current state [USA?] record >3,700 pCi/L !!!**
- **As of 10-13-2015, there are 14 homes >1,000 pCi/L**
- **Specific values are as follows: 3715, 2748, 2478, 1951, 1812, 1703, 1611, 1545, 1400, 1295, 1270, 1267, 1244, 1024 pCi/L**



# Discovery of a Very High Radon Area

Geology of the Center Valley PA Area [from a map by Avery A. Drake]





# ▶ Survey Area Geology: The 'Perfect Storm'

- **Epler Formation-Limestone, Dolomite**
- **Deposition of Reading Prong uranium bearing material**
- **Uranium mineralization at base of the Epler**
- **Most intense mineralization at brecciated thrust fault at base of Epler**
- **In carbonate soils, radium concentrates up to 15-20x the amount supported by U in bedrock**

# ▶ Survey Area Geology: The Perfect Storm

- Impermeable, B-zone soils over the brittle-fractured dolomite tends to cap the radon
- And, what do we put 12 feet into the ground?



***Ans.: basements  
to test for Rn!***



# Discovery of a Very High Radon Area

## Ongoing Soil and Rock Sampling and Rad Analysis



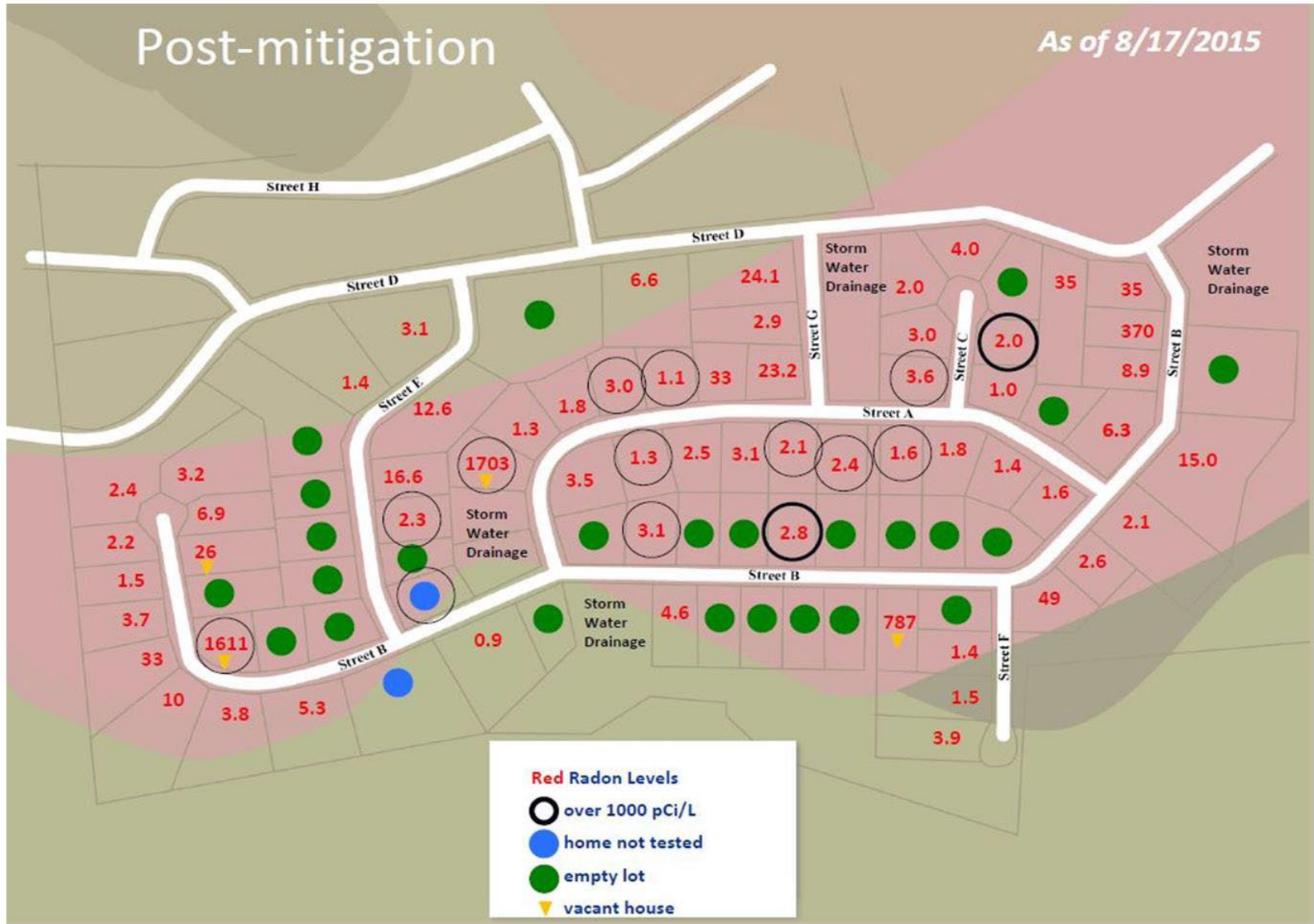
Soil Profile	Isotope	pCi/g
A Zone	Ra-226	82 pCi/g
	U-238	85 pCi/g
B Zone	Ra-226	170 pCi/g
	U-238	199 pCi/g
C Zone	Ra-226	24 pCi/g
	U-238	20 pCi/g
R Zone	Ra-226	79 pCi/g
	U-238	67 pCi/g

Above data from March 2015 samples.





# Discovery of a Very High Radon Area





# Discovery of a Very High Radon Area

## Public Meeting



News for Immediate Release

Dec. 3, 2014

### DEP Finds Record-High Radon Level in Lehigh County Home

Area residents urged to attend information meeting on Dec. 4

**Harrisburg** – The Department of Environmental Protection (DEP) has identified a home in the Center Valley area of Lehigh County with the highest home radon level ever measured in Pennsylvania. DEP encourages all area residents to have their homes tested for radon. This is especially important now that homes are winterized, limiting the amount of fresh air that will be entering those structures.

The concentration measured was 3,715 picocuries per liter (pCi/L). Additionally, several other homes in the area have had measured concentrations over 1,000 pCi/L. The U.S. Environmental Protection Agency (EPA) recommends that that any dwelling or structure with a radon concentration of more than 4 pCi/L be remediated to lower the radon concentration. In this circumstance, DEP recommended the occupants vacate the home until the measured radon concentration is verified and remediated to a level less than 4 pCi/L.





# Media Coverage

philly.com

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[http://www.philly.com/philly/news/Record-breaking\\_radon\\_levels\\_found\\_inside\\_Pa\\_home.html](http://www.philly.com/philly/news/Record-breaking_radon_levels_found_inside_Pa_home.html) accessed 8-18-2015

## ***Record-breaking radon levels found inside Pa. home***

Alex Wigglesworth, *Philly.com* Last updated: Thursday, December 4, 2014, 4:52 PM

A Lehigh County home has returned the highest concentration of radon ever measured inside a Pennsylvania dwelling, according to the state Department of Environmental Protection. The home, located in the Center Valley area, registered a measurement of 3,715 picocuries per liter of the cancer-causing radioactive gas, the DEP announced. The U.S. Environmental Protection Agency recommends any structure with a radon concentration of more than 4 picocuries per liter be remediated.

# Discovery of a Very High Radon Area

## Ongoing Efforts to Mitigate Homes

- Builders have used some RRNC methods
- Work with local mitigator to train builders on RRNC methods
- Builders are funding any needed mitigation
- BRP continues to track construction and testing
- Regular contacts with residents who have not tested or mitigated
- Studies of local rock and soils for U/Ra content
- This may be a 'perfect storm' for radon



# Discovery of a Very High Radon Area

Mitigation of the **> 3,700 pCi/L** home...

to **< 3 pCi/L!!**

1<sup>st</sup> FL >

~1,600 pCi/L



Basement >

~2,900 pCi/L



Interior ~100 uR/h ^

< Standard sealing then used subslab depressurization. >



^ Ventilated basement to perform work.





# **Conclusion**

**PA is [perhaps] the most highly impacted state with respect to indoor radon, and has one of the best programs to mitigate and address the risk to the public and associated issues... but, there is still work to be done.**



# The PA 'Radon Monitoring Team'



**R-L: Bob Lewis, Denise Bleiler,  
Bob Smith\* and Matt Shields**

\* Retired DER/DCNR Geologist

**Andrew Taverna**





Thank You

Questions?



**pennsylvania**

DEPARTMENT OF ENVIRONMENTAL PROTECTION



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