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DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Radiation Protection

PA Radon Program - An Update

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ISCORS Meeting

December 6, 2018

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Overview of This Presentation

- Provide short history of radon in PA
- Review current PA Radon Program
- Note health effects
- Explain radon testing and mitigation
- Give an overview of several radon studies
- Describe a recently discovered very high radon area, and actions taken
- Note some needed initiatives
- Time for Q&A

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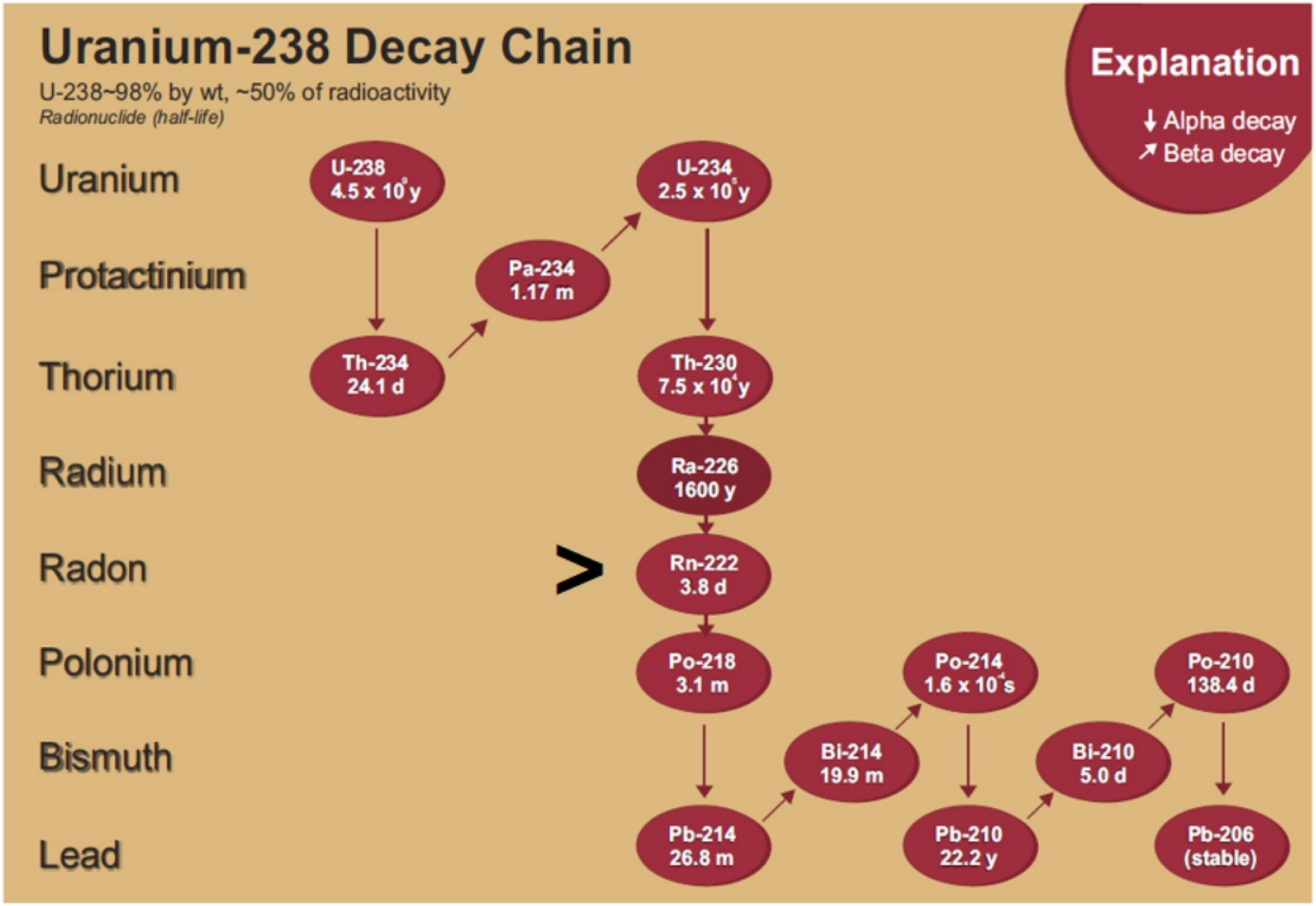
Natural Uranium & Radon

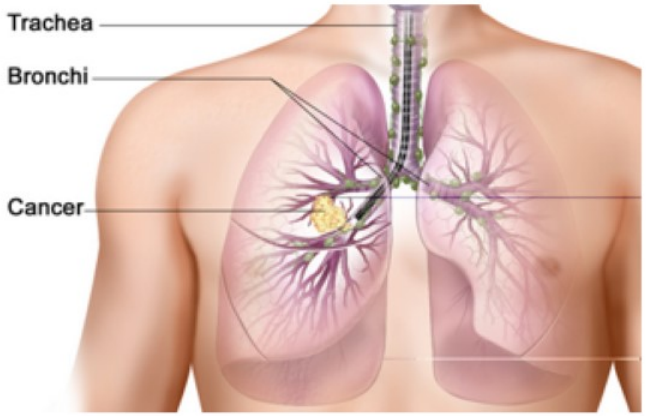


Radiation & Radon Exposure

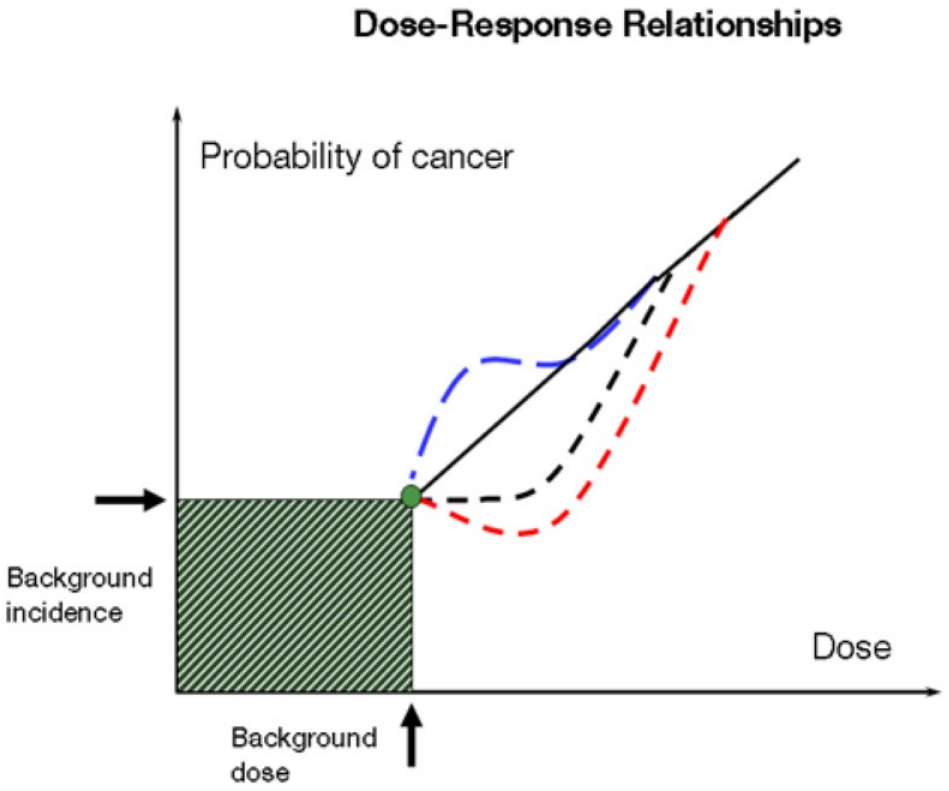
Biological Effects

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.



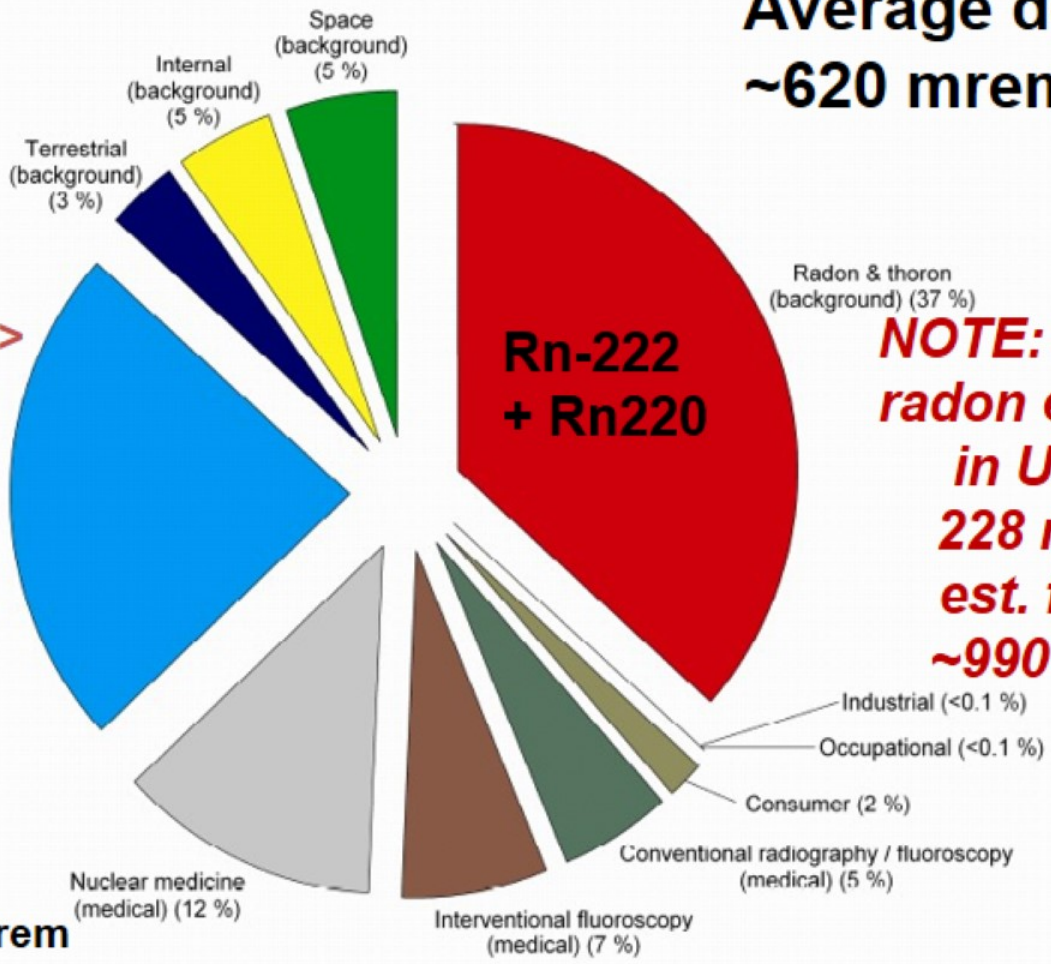
See NCRP Report No. 136 (2001) for a detailed description of the contrasting types of dose-response relationships.

Average Radiation Dose - USA

All Exposure Categories
Collective Effective Dose (percent), 2006

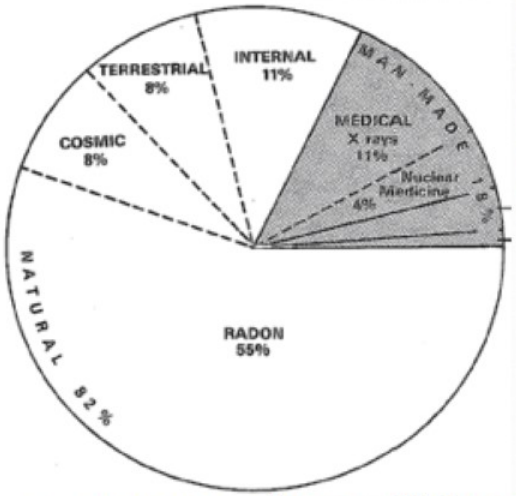
NCRP Rpt. 160

Average dose ~620 mrem/yr



Medical Dose from CT >

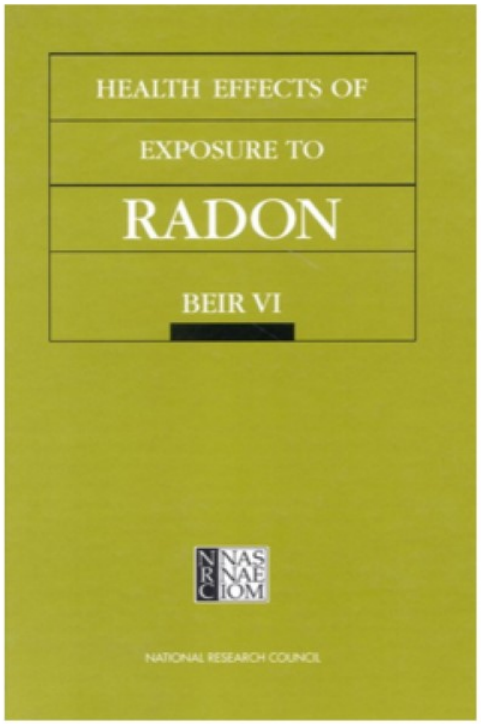
NOTE: average radon eff. dose in USA is 228 mrem; est. for PA ~990 mrem



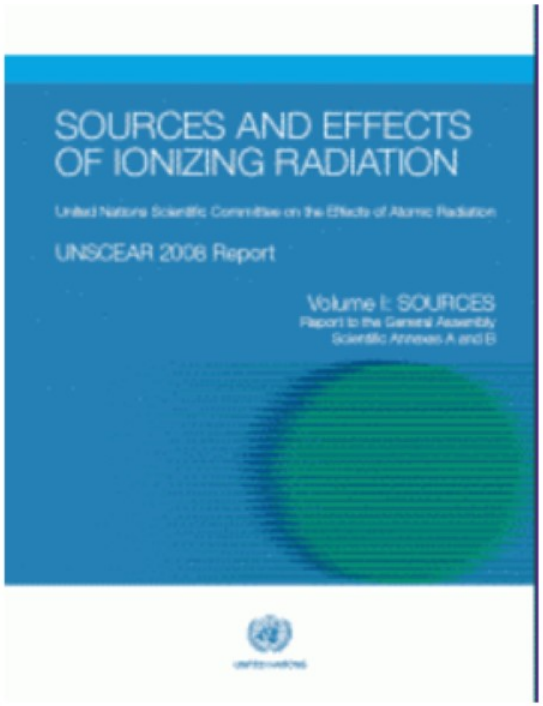
^ 1986 Ave: ~360 mrem

Rev 10-14-2015

Radon Studies, Reports and Papers



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,[1] E. Georg Luebeck,[1] Daniel Krewski,[2] and Jan M. Zielinski[2]

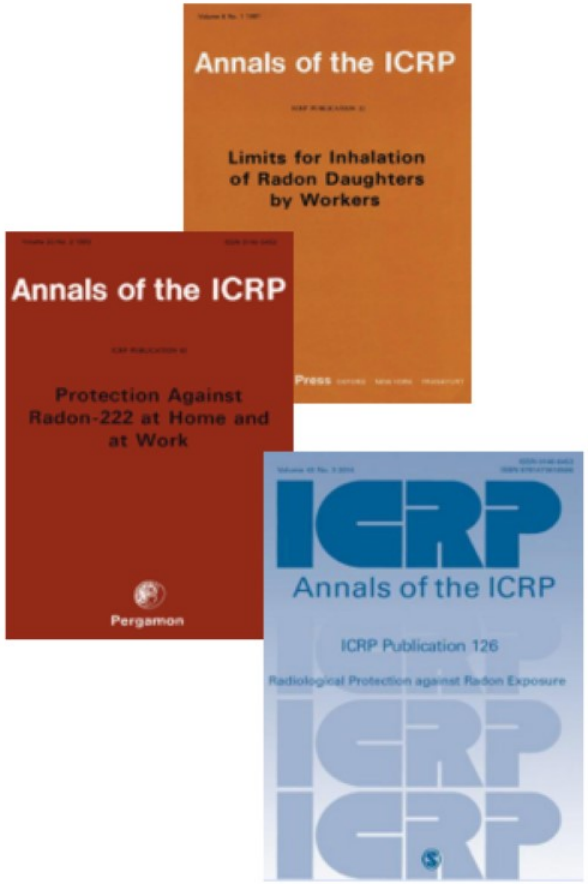
Much of our knowledge regarding the interaction of radon and tobacco smoke in the etiology of human lung cancer derives from studies of uranium miners. In this article, we present a re-analysis of lung cancer mortality in the Colorado Plateau miners' cohort within the framework of the two-mutation clonal 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.

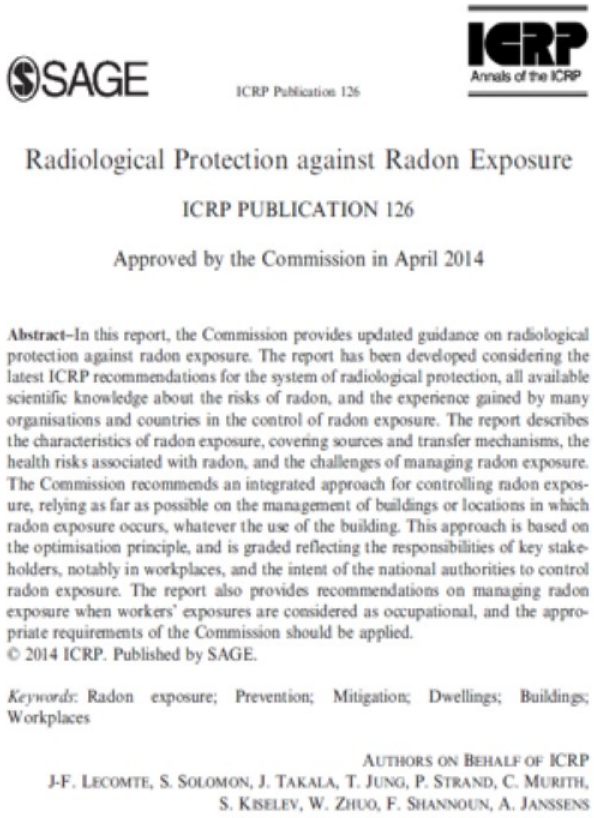
EXAMPLE

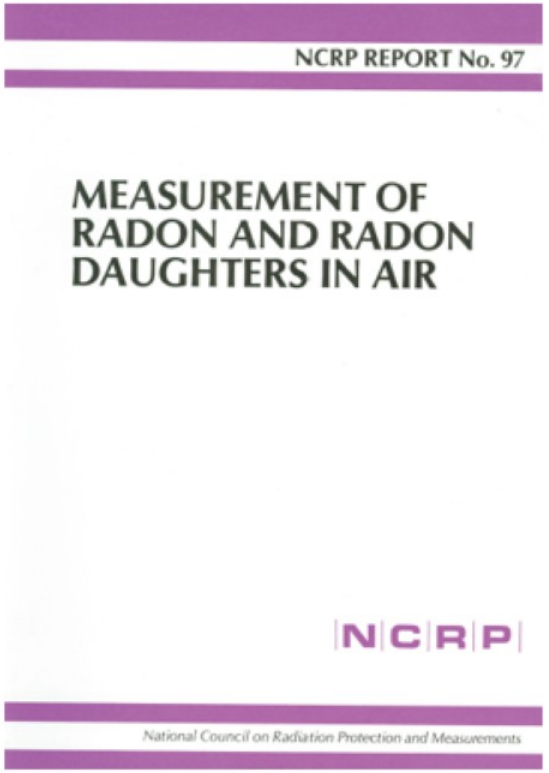
Uranium Miner Studies

Radon Studies, Reports and Papers



ICRP Reports





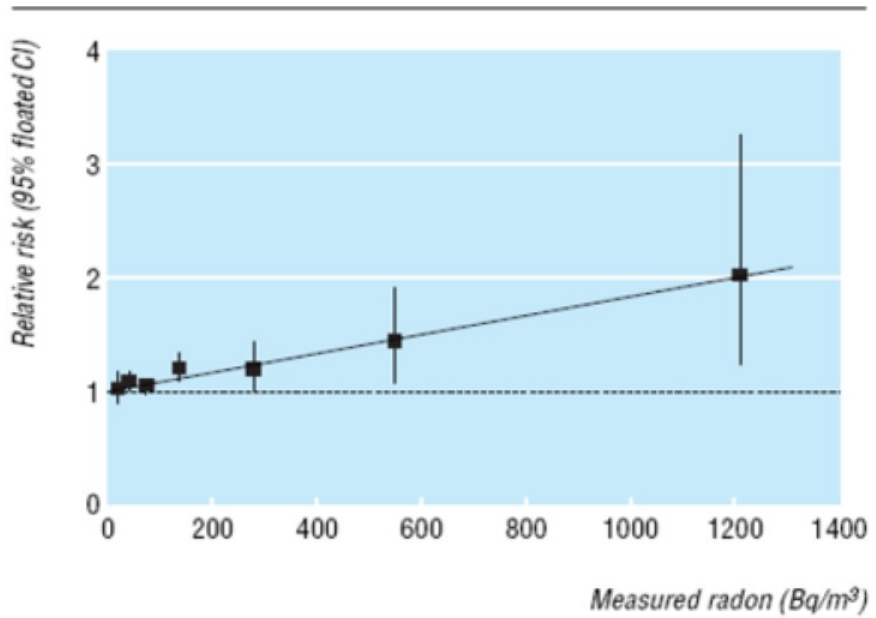
NCRP Reports

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

Radon Studies, Reports and Papers

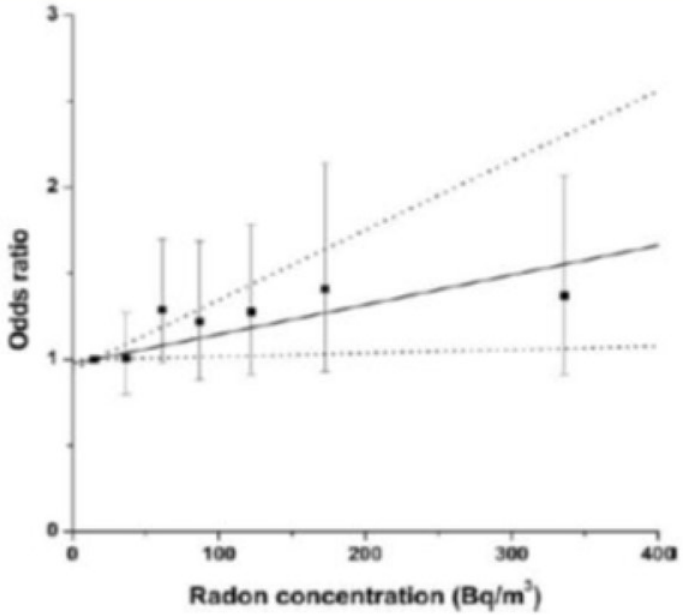
Pooled Residential Studies

Europe



Darby et al 2005

North America

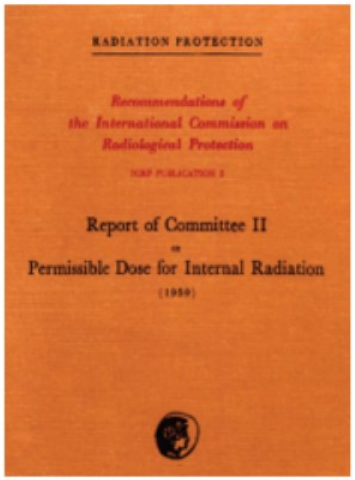


Krewski et al 2005

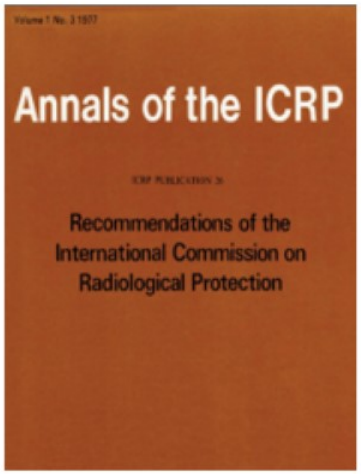
From Harrison 2014

ICRP RP Recommendations

- **Justification**
- **Optimization [ALARA]**
- **Limitation**



ICRP 2

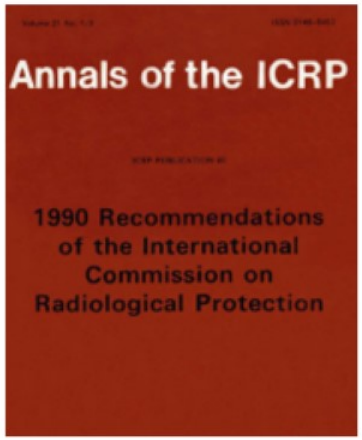


ICRP 26/30

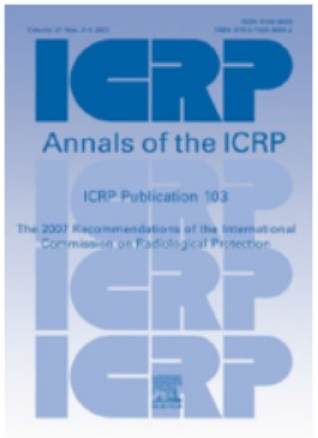
> Existing Conditions

> Planned Scenarios

> Emergencies [for radon?]



ICRP 60



ICRP 103

Radiation Dose & Control Limits

*** **Radon** ***

EPA: 4 pCi/L (148 Bq/m^3) public 'action level'

NRC: 30 pCi/L (1,110 Bq/m^3) workers [10CFR20]

OSHA: 100 pCi/L (3,700 Bq/m^3) workers [29CFR1910.1096

ICRP: 300 Bq/m^3 (8.1 pCi/L) public 'reference level'

Canada: 200 Bq/m^3 (5.4 pCi/L) public ref. level

MSHA: 4 WLM/yr workers [30CFR57.5038]

Note: 1 pCi/L = 37 Bq/m^3

ICRP

NCRP National Council on Radiation Protection & Measurements

UNITED STATES DEPARTMENT OF LABOR

Occupational Exposure

Review Paper

By Robert K. Lewis

Health Physics October 2016, Volume 111, Number 4

RADON IN THE WORKPLACE: THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) IONIZING RADIATION STANDARD

Abstract—**On 29 December 1970, the Occupational Safety and Health Act of 1970 established the Occupational Safety and Health Administration (OSHA). This article on OSHA, Title 29, Part 1910.1096 Ionizing Radiation standard was written to increase awareness of the employer, the workforce, state and federal governments, and those in the radon industry who perform radon testing and radon mitigation of the existence of these regulations, particularly the radon relevant aspect of the regulations. This review paper was also written to try to explain what can sometimes be complicated regulations. As the author works within the Radon Division of the Pennsylvania Department of Environmental Protection, Bureau of Radiation Protection, the exclusive focus of the article is on radon. The 1910.1096 standard obviously covers many other aspects of radiation and radiation safety in the work place.**
Health Phys. 111(4):374–380; 2016

Key words: ^{222}Rn; occupational safety; radon; safety standards

Radon in Soil & Groundwater

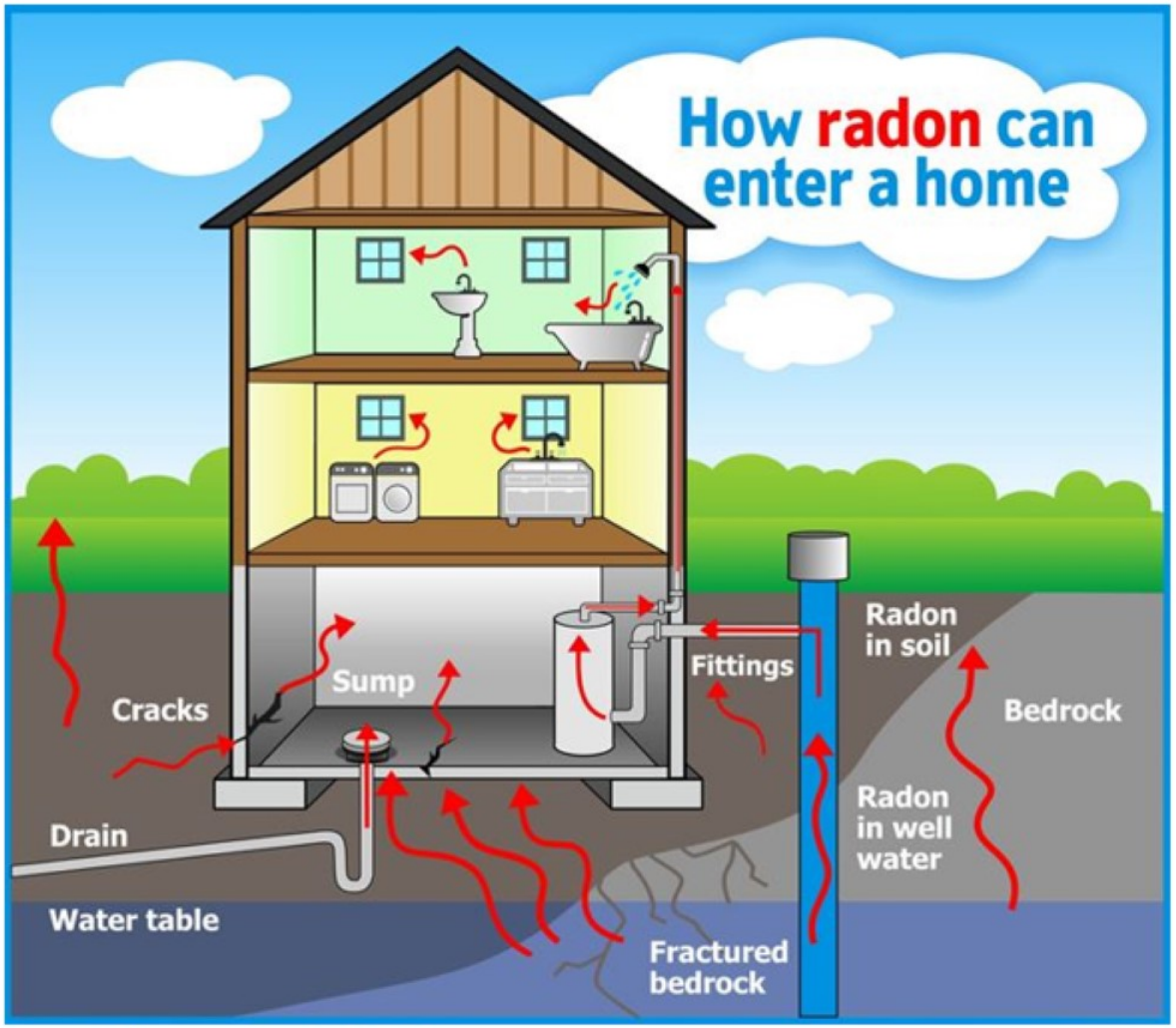


Figure by PA DEP

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

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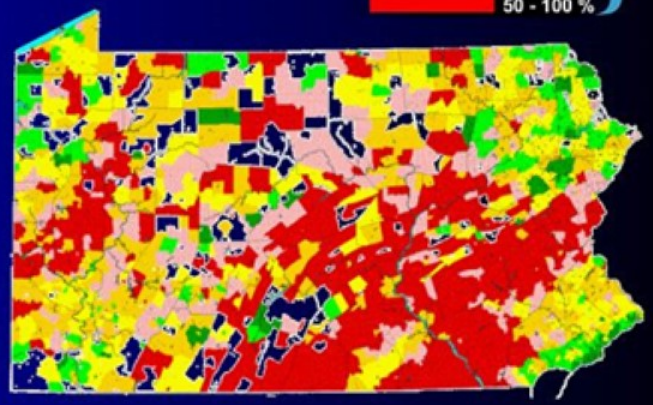
Dec. 1984 - the "Index House"

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

Rn Radon
Atomic Number: 86
Atomic Mass: (222)

Zip Code map of Pennsylvania

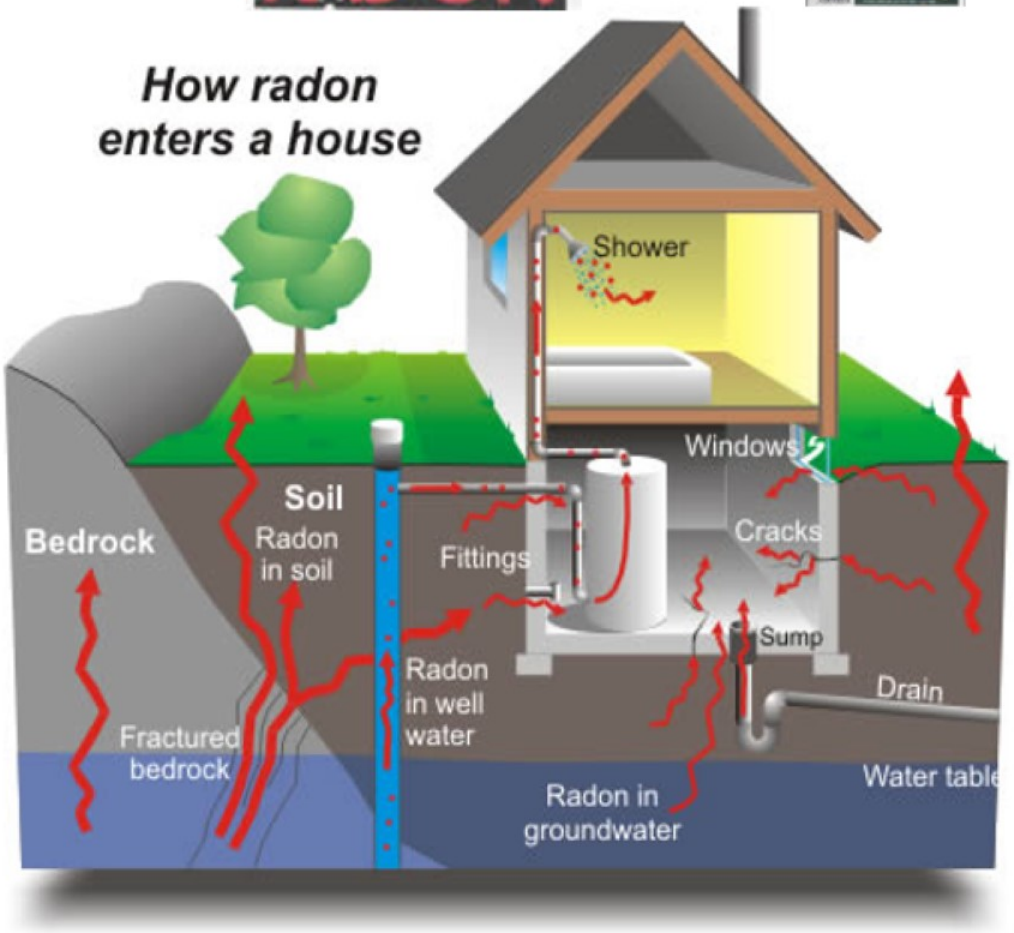
This map of Pennsylvania shows the % of known test results that exceed EPA's action guideline of 4.0 picocuries per liter. It is estimated that over 40% of the homes in Pennsylvania exceed the EPA's action guideline.

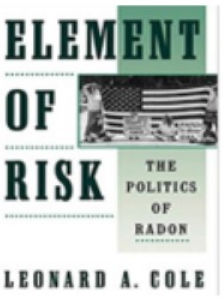


Radon-222

- **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!!**





Controversy with the radon action level.

The 1984 'Index House'

PENNSYLVANIA GEOLOGY

PENNSYLVANIA GEOLOGY is published bimonthly by the Bureau of Topographic and Geologic Survey, Pennsylvania Department of Environmental Resources, Harrisburg, Pennsylvania 17120.
Editor, Donald M. Hoskins
Associate Editor, Christine M. Dodge
Articles may be reprinted from this magazine if credit is given to the Topographic and Geologic Survey.

VOL. 18, NO. 2 APRIL 1987

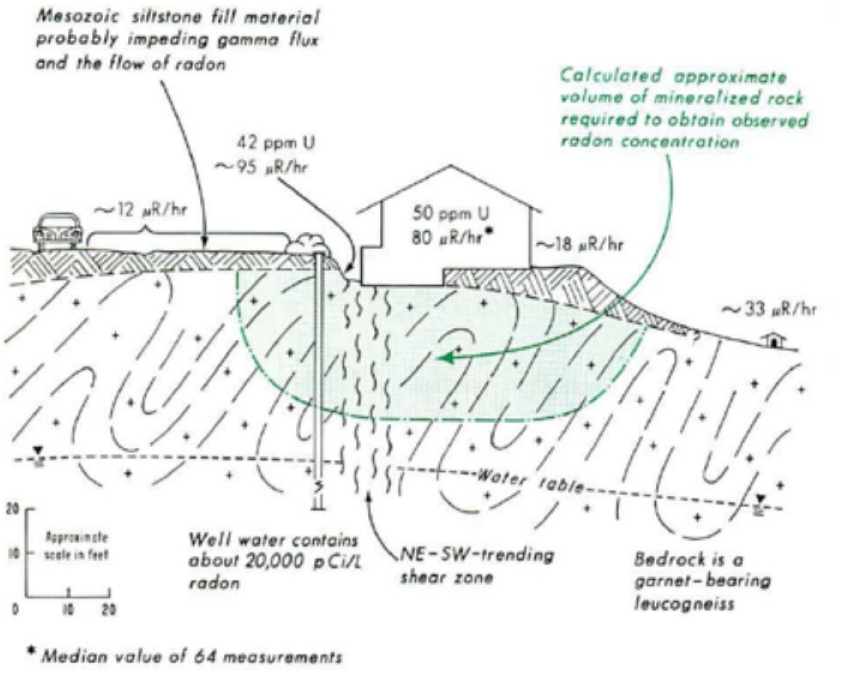


Figure 1. Generalized cross section of the "Index House" site as

Radon: A Profound Case

by R. C. Smith, II, Pennsylvania Geological Survey
M. A. Reilly, Pennsylvania Bureau of Radiation Protection
A. W. Rose, The Pennsylvania State University
J. H. Barnes, Pennsylvania Geological Survey
S. W. Berkheiser, Jr., Pennsylvania Geological Survey

In late December 1984, the world's most severe indoor radon problem to date was discovered in a house in Colebrookdale Township, Berks County, in the Reading Prong physiographic province of Pennsylvania. Radon is a naturally occurring, colorless, odorless, inert, but radioactive gas, with a half-life of 3.8 days. It is a decay product of the most abundant naturally occurring isotope of uranium, U^{238}, and has radium as its immediate radioactive parent. Uranium and radon are found nearly everywhere in very small concentrations. Radon and its daughter products decay by the emission of alpha particles, essentially helium nuclei (two protons and two neutrons) carrying a charge of +2. Because of their large mass and charge, alpha particles travel only a short distance through body tissue, and have the capability of causing extensive damage when they encounter living tissue. The risk of lung cancer is understood to be proportional to the amount of exposure to radon decay products in air.

Radon is measured in radioactivity units called picocuries (pCi). One picocurie of radon is approximately the quantity that would yield the disintegration of two atoms per minute. The U. S. Environmental Protection Agency has suggested that the concentration of radon in the air of residential buildings should not exceed 4 picocuries of radon per liter (quart) of air. The house in Colebrookdale Township, the "Index House," was found to contain 2,500 pCi Rn/L (picocuries of radon per liter) for sustained periods.

Radiation Control in USA

In PA

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

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.

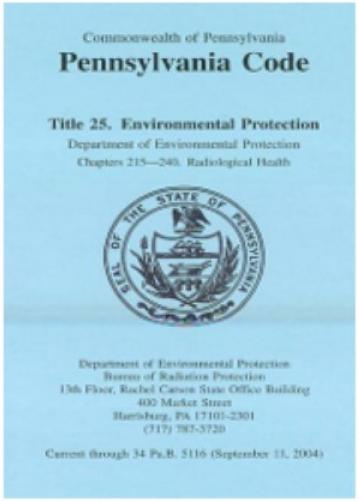
- 220. Notice, Instructions & Reports ….

- 221. X-rays in the Healing Arts

- 230. Packaging & Transport of RAM

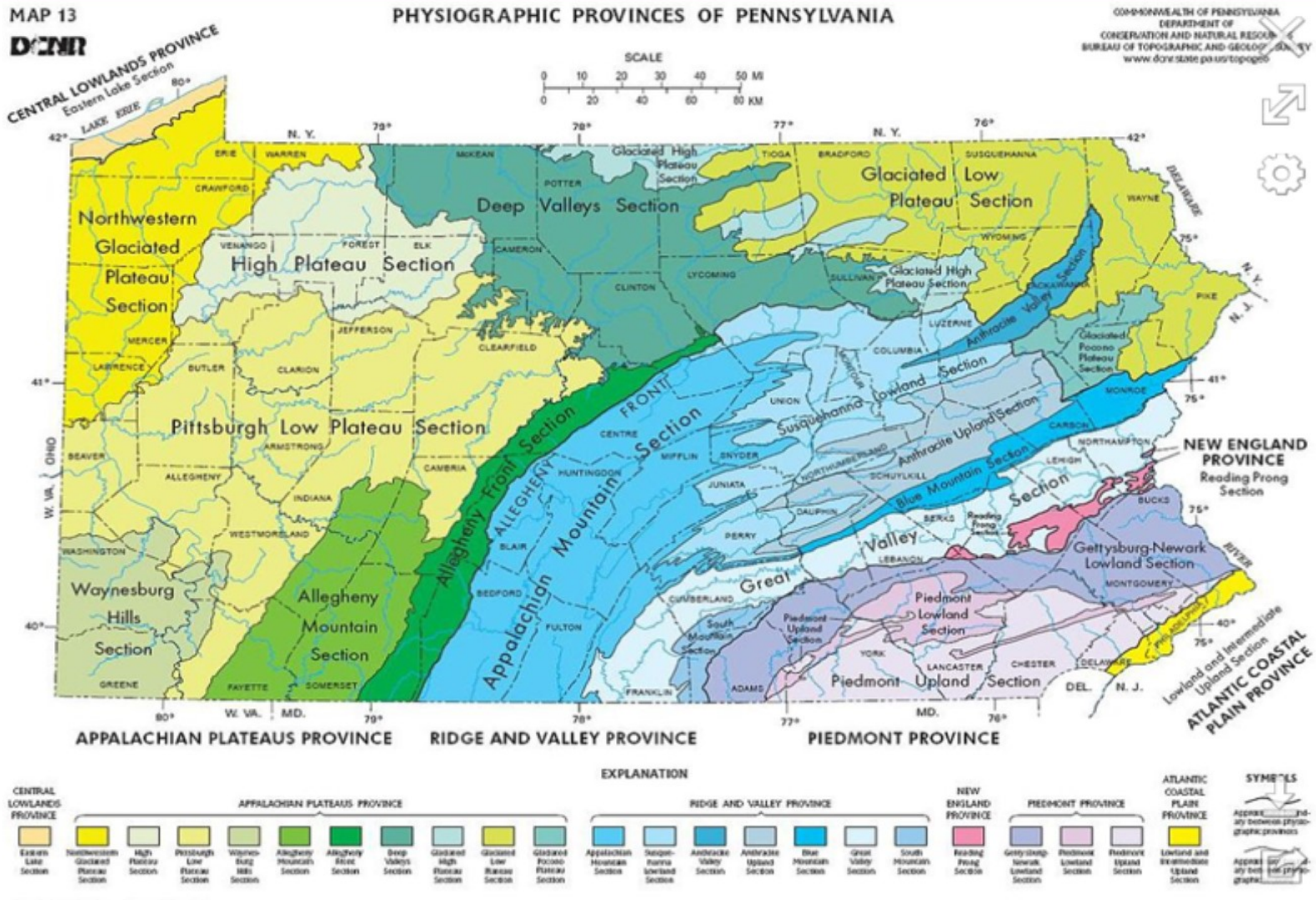
- 236. LLRW Management & Disposal

- 240. Radon Certification



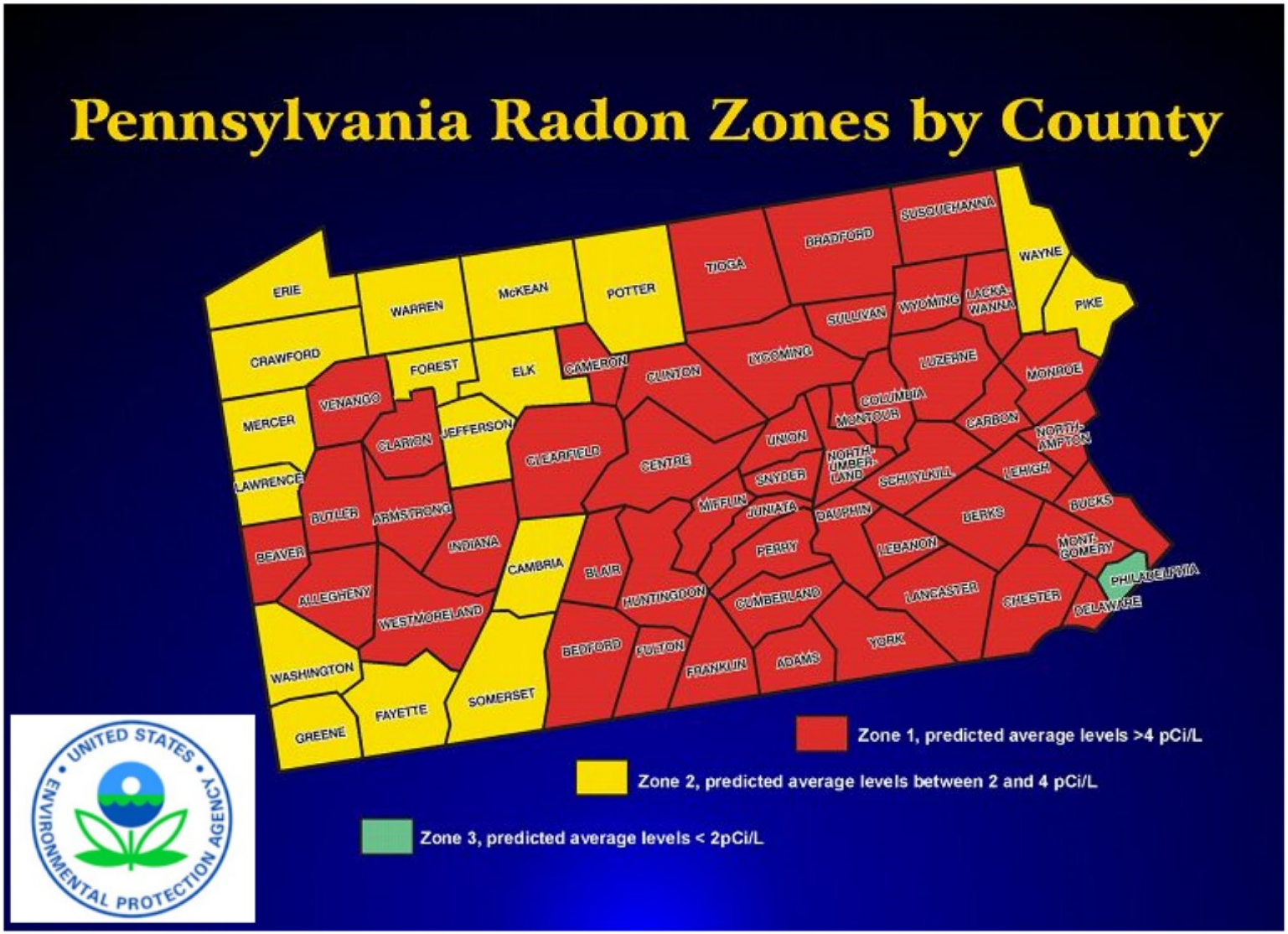
*Note: Partial list of Chapters; and in Nov. 2001 PA incorporated NRC regs in Title 10 CFR by reference

High Radon in Reading Prong



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

EPA - Radon Zones in PA



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'

* Update effective January 2019

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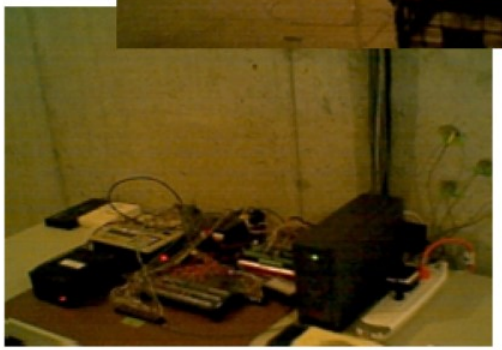
PA Moisture Study

Movement and Sources of Basement Ventilation Air and Moisture During ASD Radon Control
Additional Analysis

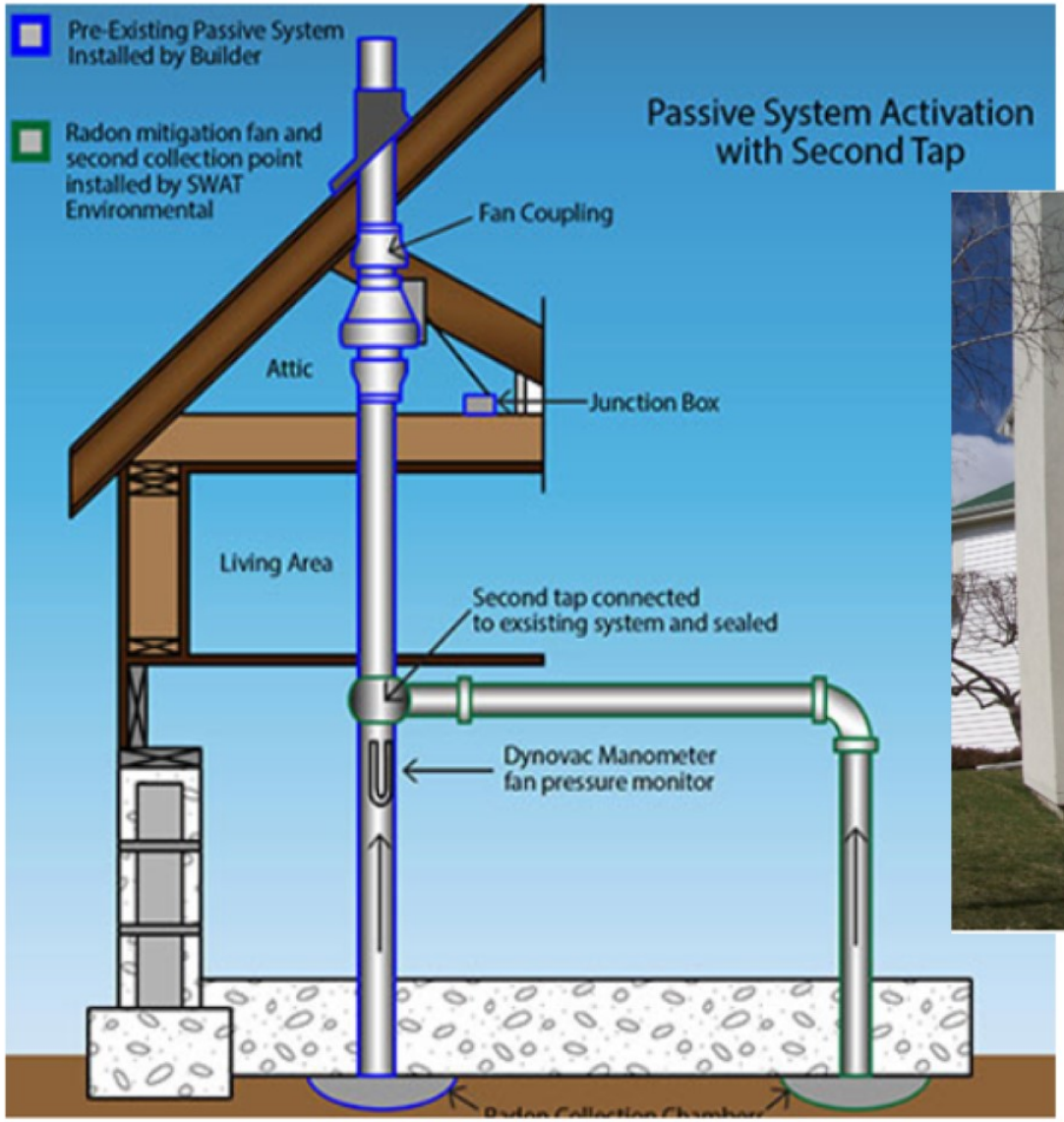
May 20, 2009

Table 6. Summary of Moisture, Radon, and Interzonal Flows under Different Seasons

House #	Season	ASD Config	Average AH (g/m^3) Bsmt Air	Upstairs Air	Outdoor Air	Soil Gas	Radon Concentrations (pCi/L) Outdoor Air (est)	Upstairs Air	Bsmt Air	Soil Gas	Upstairs (cfm)
PA01	Winter	Off	5.3	5.0	3.3	12	0.3	39	60	230	11
		On full	5.8	5.3	4.9	12	0.3	0.4	0.4	240	32
	Spring	Off	7.3	6.9	7.4	12	0.3	11	50	380	6.8
		On full	7.0	7.2	9.1	13	0.3	0.4	1.3	320	2.8
	Summer	Off	9.7	9.3	17	15	0.3	21	26	930	18
		On full	9.6	9.1	16	16	0.3	1.0	0.8	360	33
	Fall	Off	9.7	9.3	9.1	15	0.3	17	55	910	2.4
		On mod	10	11	13	15	0.3	0.5	0.7	470	4.4



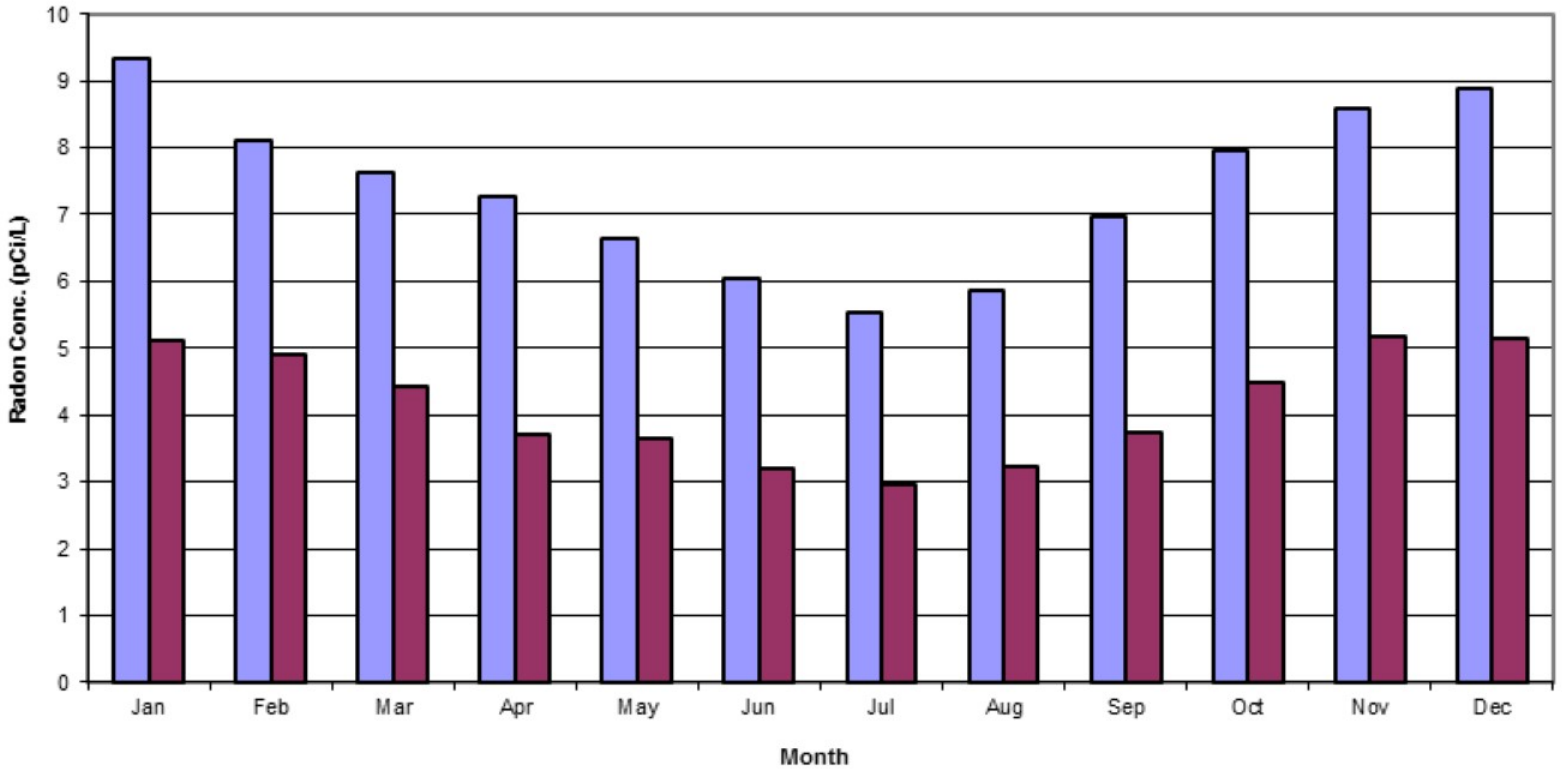
Radon Mitigation



Re-entrainment Study 2018-2019

Sub-slab Depressurization

PA Radon Database



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

< Basement; ave. ~7 pCi/L

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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

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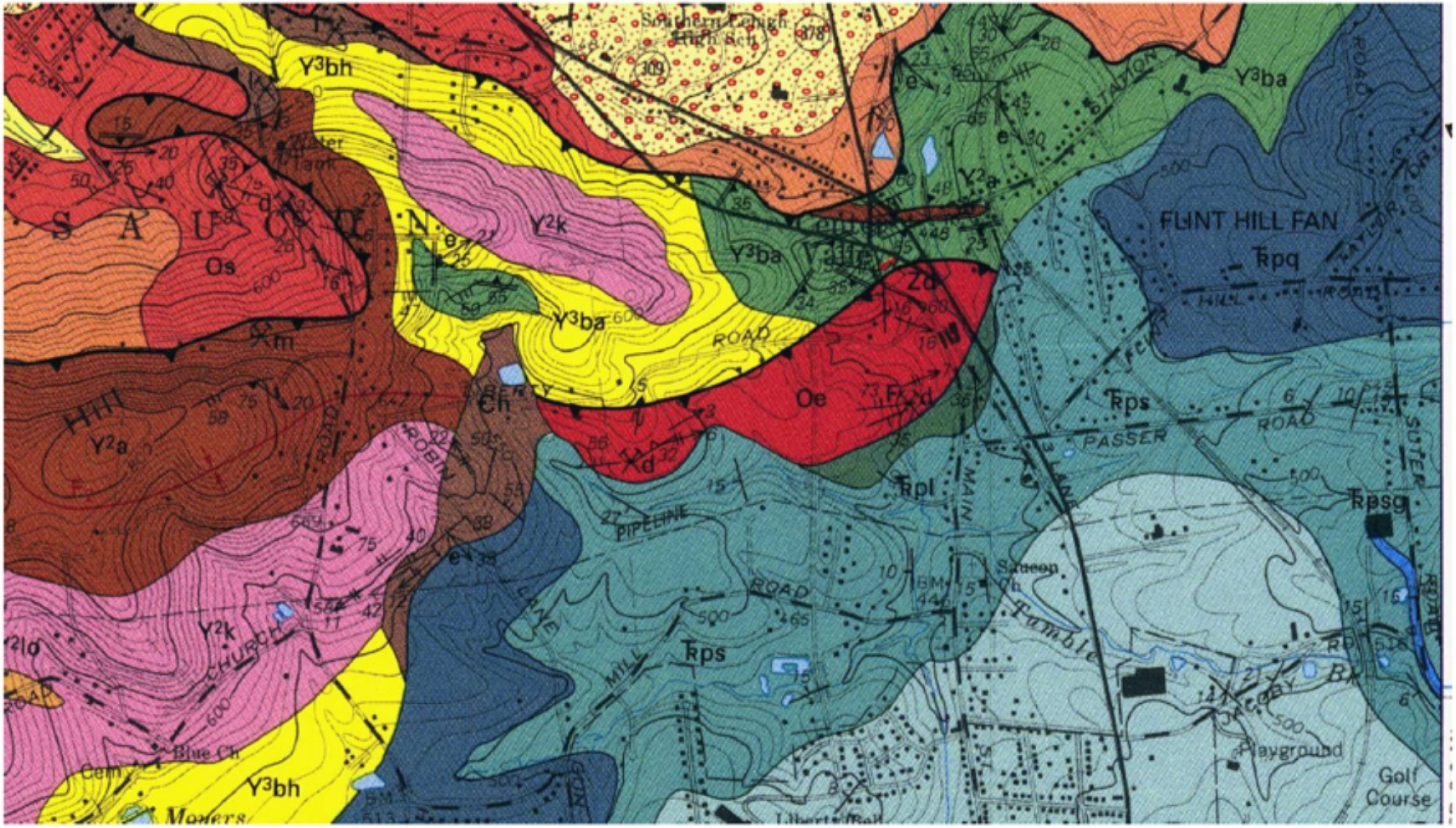
Survey Area Geology: The Perfect Storm

- **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

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



Discovery of a Very High Radon Area

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**
- **In late 2014 one home over 2,700 pCi/L; another with over 3,700 pCi/L**
- **In 2016 one over 6,100 pCi/L**
- **In 2017 one over 17,000 pCi/L !**

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.

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Radon Levels Over 1,000 pCi/L

- **Current state [world?] record >17,520 pCi/L !!!**
- **As of 12-3-2018, there are 19 homes over 1,000 pCi/L**
- **Specific values >1,000 pCi/L are as follows:**

  1611, 2558, 1545, 2478, 1703, 1024, 1244, 1812, 1270, 6176, 1414, 3715, 1951, 1295, 1267, 2748, 5336, 2182, 17520 pCi/L

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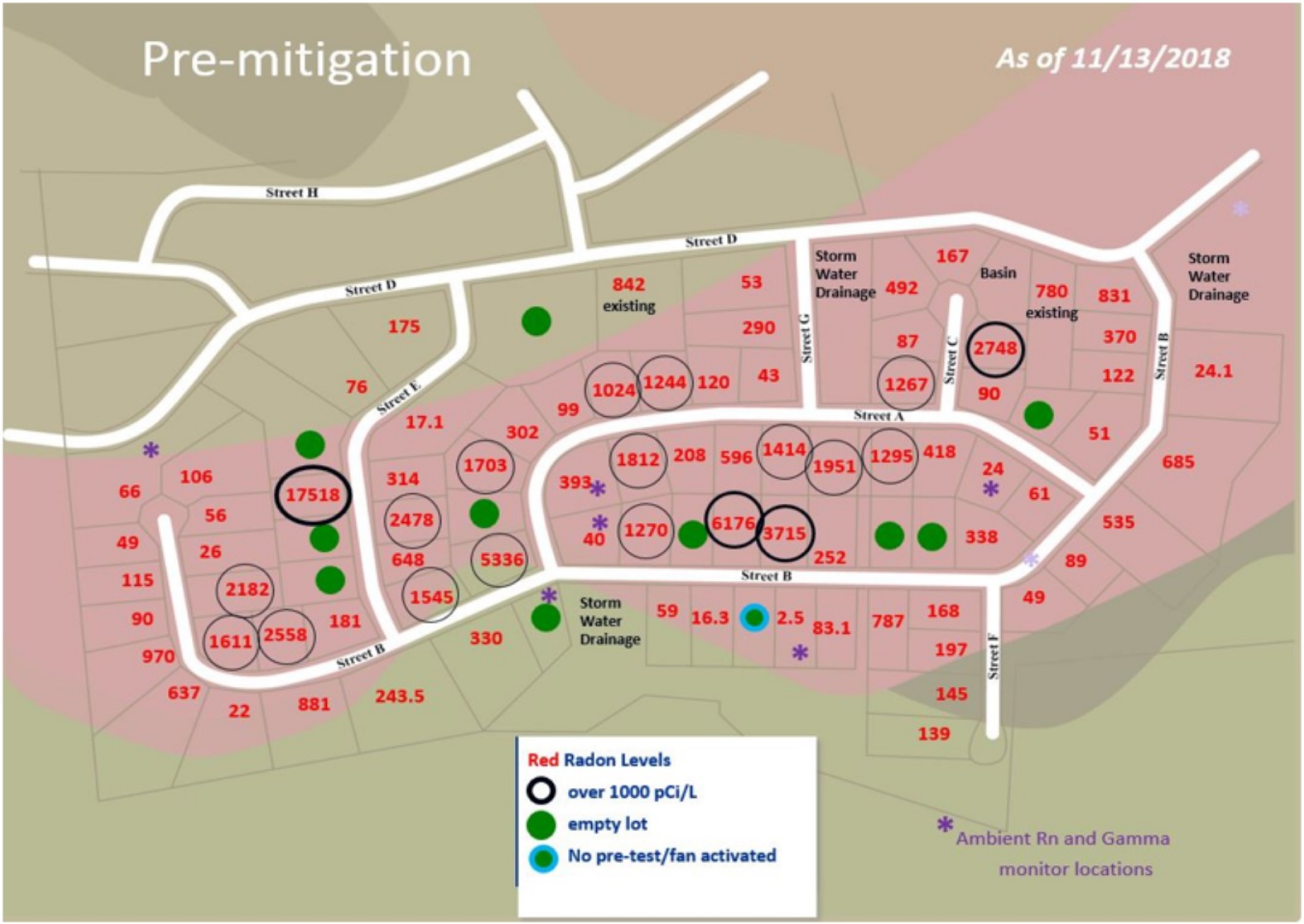
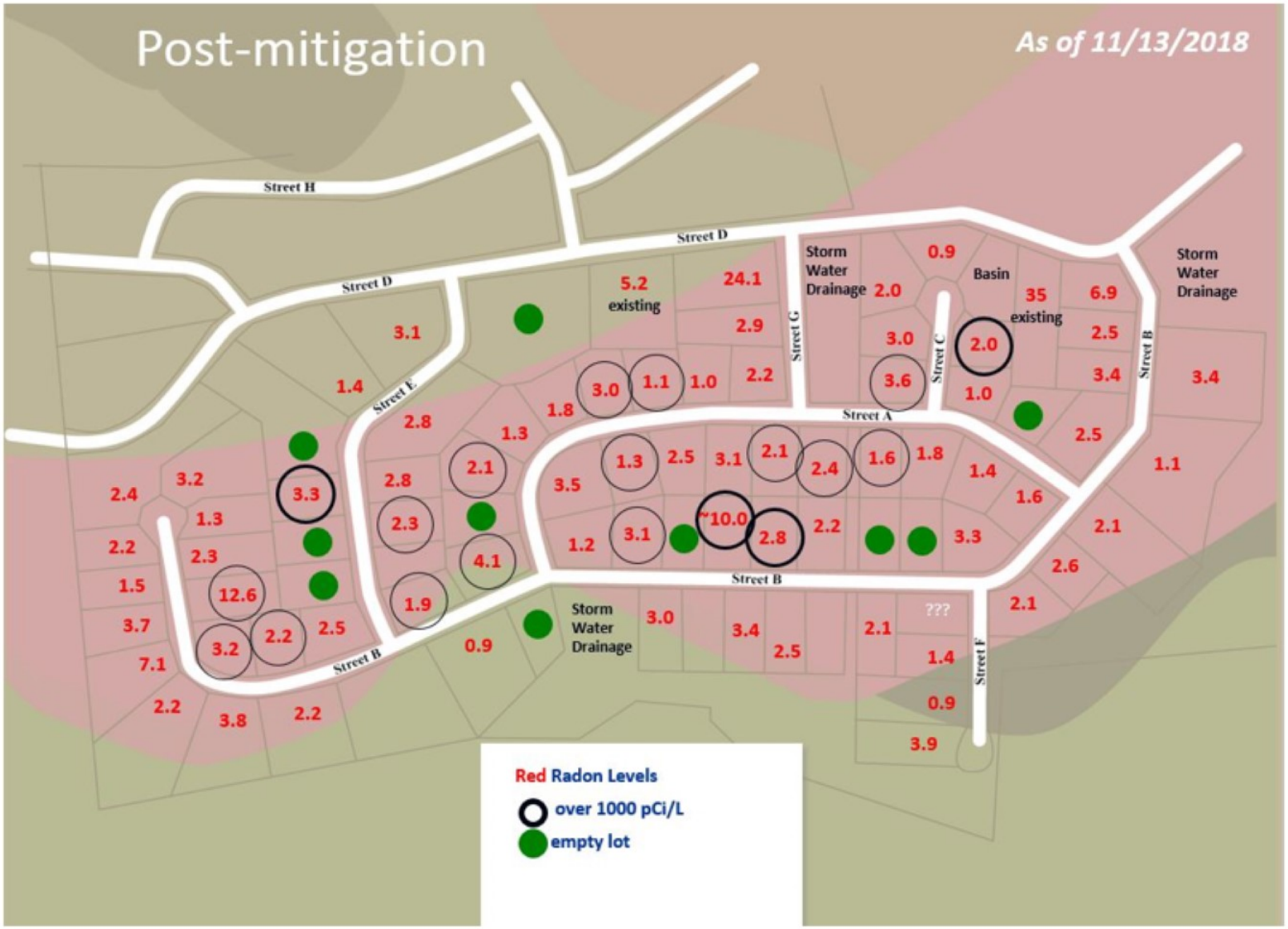
Discovery of a Very High Radon Area



Discovery of a Very High Radon Area



High Radon Area Tally

	Count	Percentage
0 - 4 pCi/L	0	0 %
4 - 20 pCi/L	0	0%
20 - 100 pCi/L	20	29 %
100 – 1,000 pCi/L	30	43 %
> 1,000 pCi/L	19	28 %

100% of these results are over 20 pCi/L.
Typically, only 40% of results in PA are over 4 pCi/L

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Discovery of a Very High Radon Area

Mitigation of the > 3,700 pCi/L home…

to < 3 pCi/L!!

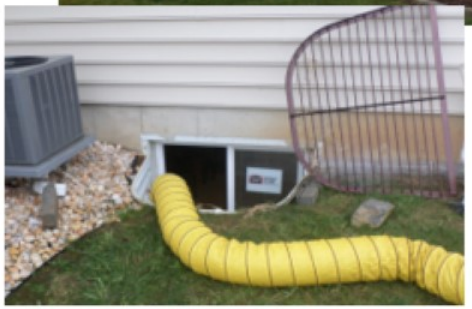
1st FL >

~1,600 pCi/L

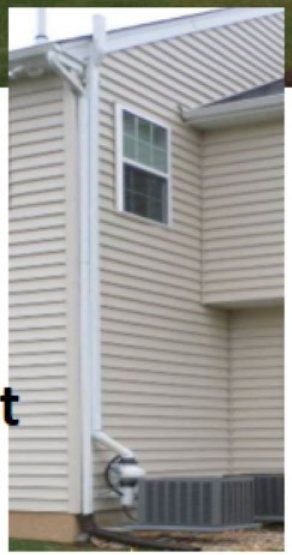
Basement >

~2,900 pCi/L

Interior ~100 uR/h ^



^ Ventilated basement to perform work.



< Standard sealing then used subslab depressurization. >

Discovery of a Very High Radon Area

Public Meeting

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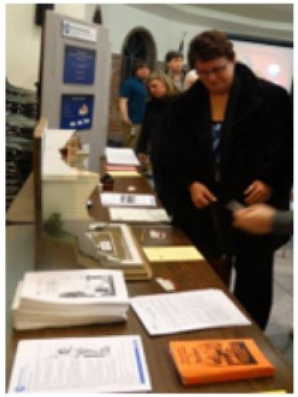
News for Immediate Release

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.



Discovery of a Very High Radon Area

Ongoing Efforts to Mitigate Homes

- Builders have used some RRNC methods
- Local mitigator training builders on RRNC methods
- Builders are funding any needed mitigation
- Builder also installing alarms on mitigation systems
- 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
- Planning another public meeting

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Needed Initiatives

PA 'Wish List' =>

- Require radon testing for all property sales; with disclosure to the potential buyer
- Require all schools to be tested on a regular basis
- Amend the state building code to require 'radon resistant new construction' methods

EPA – continue states $ support thru SIRG!

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'

L to R: Bob Smith*, Denise Bleiler and Bob Lewis

***** Retired DER/DCNR Geologist

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Thank You

Questions?

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