“Radon In New Hampshire”

New Hampshire Radon Program
NHDES Air Resources Division
Bureau of Environmental Health/Radon Program
Owen David

Program Specialist II

Los Alamos National Laboratory Chemistry Division

Periodic Table of the Elements

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	11B	12B	3A	4A	5A	6A	7A	8A
1 H hydrogen 1.008																	2 He helium 4.003
3 Li lithium 6.941	4 Be beryllium 9.012											5 B boron 10.81	6 C carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18
11 Na sodium 22.99	12 Mg magnesium 24.31											13 Al aluminum 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.07	17 Cl chlorine 35.45	18 Ar argon 39.95
19 K potassium 39.10	20 Ca calcium 40.08	21 Sc scandium 44.96	22 Ti titanium 47.88	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn manganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93	28 Ni nickel 58.69	29 Cu copper 63.55	30 Zn zinc 65.39	31 Ga gallium 69.72	32 Ge germanium 72.58	33 As arsenic 74.92	34 Se selenium 78.96	35 Br bromine 79.90	36 Kr krypton 83.80
37 Rb rubidium 85.47	38 Sr strontium 87.62	39 Y yttrium 88.91	40 Zr zirconium 91.22	41 Nb niobium 92.91	42 Mo molybdenum 95.94	43 Tc technetium (98)	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs cesium 132.9	56 Ba barium 137.3	57 La* lanthanum 138.9	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.9	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 190.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.5	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 208.9	84 Po polonium (209)	85 At astatine (210)	86 Rn radon (222)
87 Fr francium (223)	88 Ra radium (226)	89 Ac~ actinium (227)	104 Rf rutherfordium (257)	105 Db dubnium (260)	106 Sg seaborgium (263)	107 Bh bohrium (262)	108 Hs hassium (265)	109 Mt meitnerium (266)	110 Ds darmstadtium (271)	111 Uuu (272)	112 Uub (277)		114 Uuq (296)		116 Uuh (298)		118 Uuo (?)

Lanthanide Series*	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium (147)	62 Sm samarium (150.4)	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.0	71 Lu lutetium 175.0
Actinide Series~	90 Th thorium 232.0	91 Pa protactinium (231)	92 U uranium (238)	93 Np neptunium (237)	94 Pu plutonium (242)	95 Am americium (243)	96 Cm curium (247)	97 Bk berkelium (247)	98 Cf californium (249)	99 Es einsteinium (254)	100 Fm fermium (253)	101 Md mendelevium (256)	102 No nobelium (254)	103 Lr lawrencium (257)

Los Alamos NATIONAL LABORATORY

CHEMISTRY

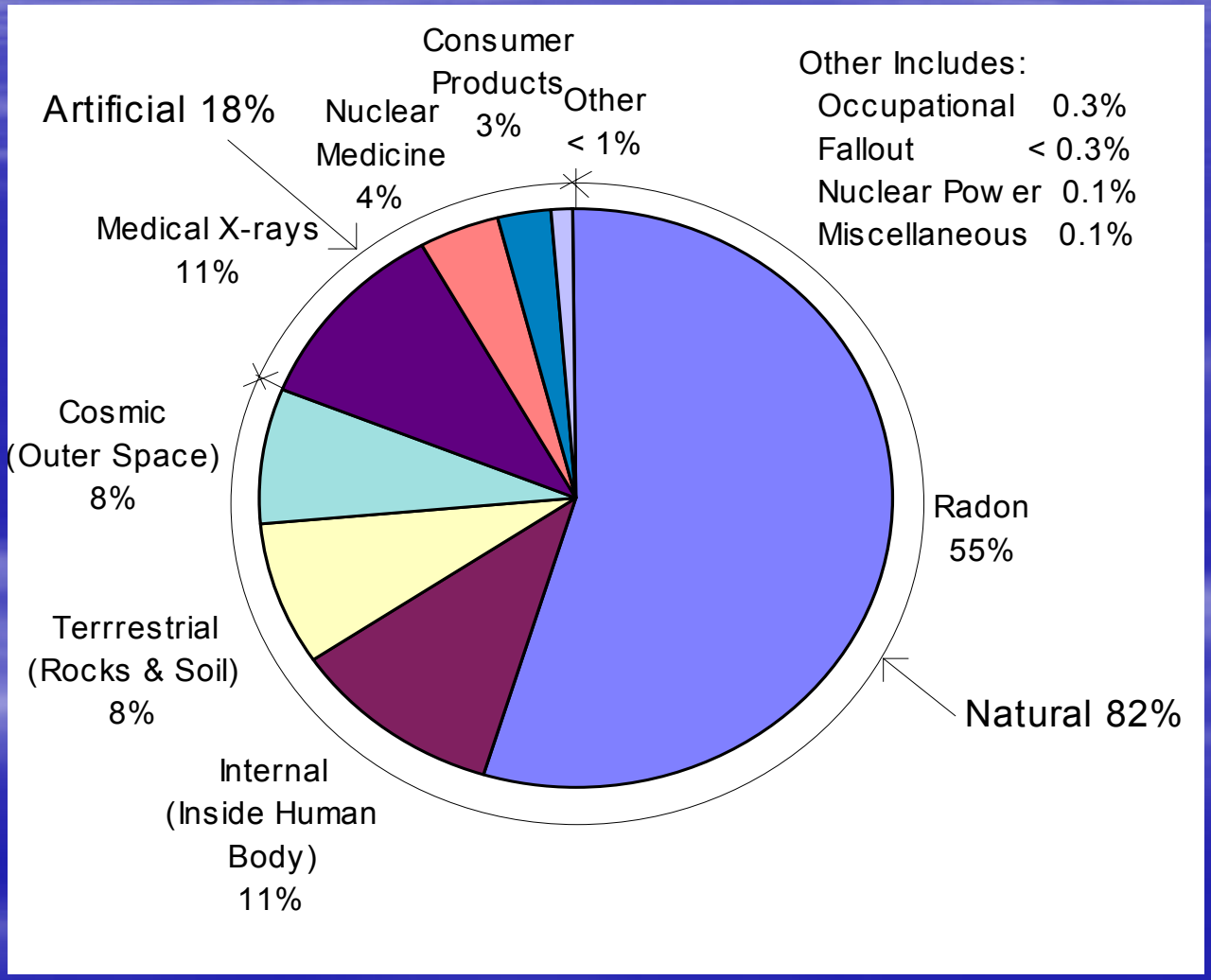
element names in blue are liquids at room temperature
element names in red are gases at room temperature
element names in black are solids at room temperature

^{238}Uranium Decay Series

Uranium	^{238}U	4.51 E9 Years	Alpha
Thorium	^{234}Th	24.1 Days	Beta & Gamma
Protactinium	$^{234}Pa^{m}$	1.17 Minutes	Beta & Gamma
Uranium	^{234}U	2.47 E5 Years	Alpha & Gamma
Thorium	^{230}Th	7.7 E4 Years	Alpha & Gamma
Radium	^{226}Ra	1602 Years	Alpha & Gamma
Radon	^{222}Rn	3.823 Days	Alpha & Gamma
Polonium	^{218}Po	3.05 Minutes	Alpha & Beta
Lead	^{214}Pb	26.8 Minutes	Beta & Gamma
Bismuth	^{214}Bi	19.7 Minutes	Beta & Gamma
Polonium	^{214}Po	164 μSeconds	Alpha & Gamma
Lead	^{210}Pb	21 Years	Beta & Gamma
Bismuth	^{210}Bi	5.01 Days	Beta
Polonium	^{210}Po	138.4 Days	Alpha & Gamma
Lead	^{206}Pb	Stable	None

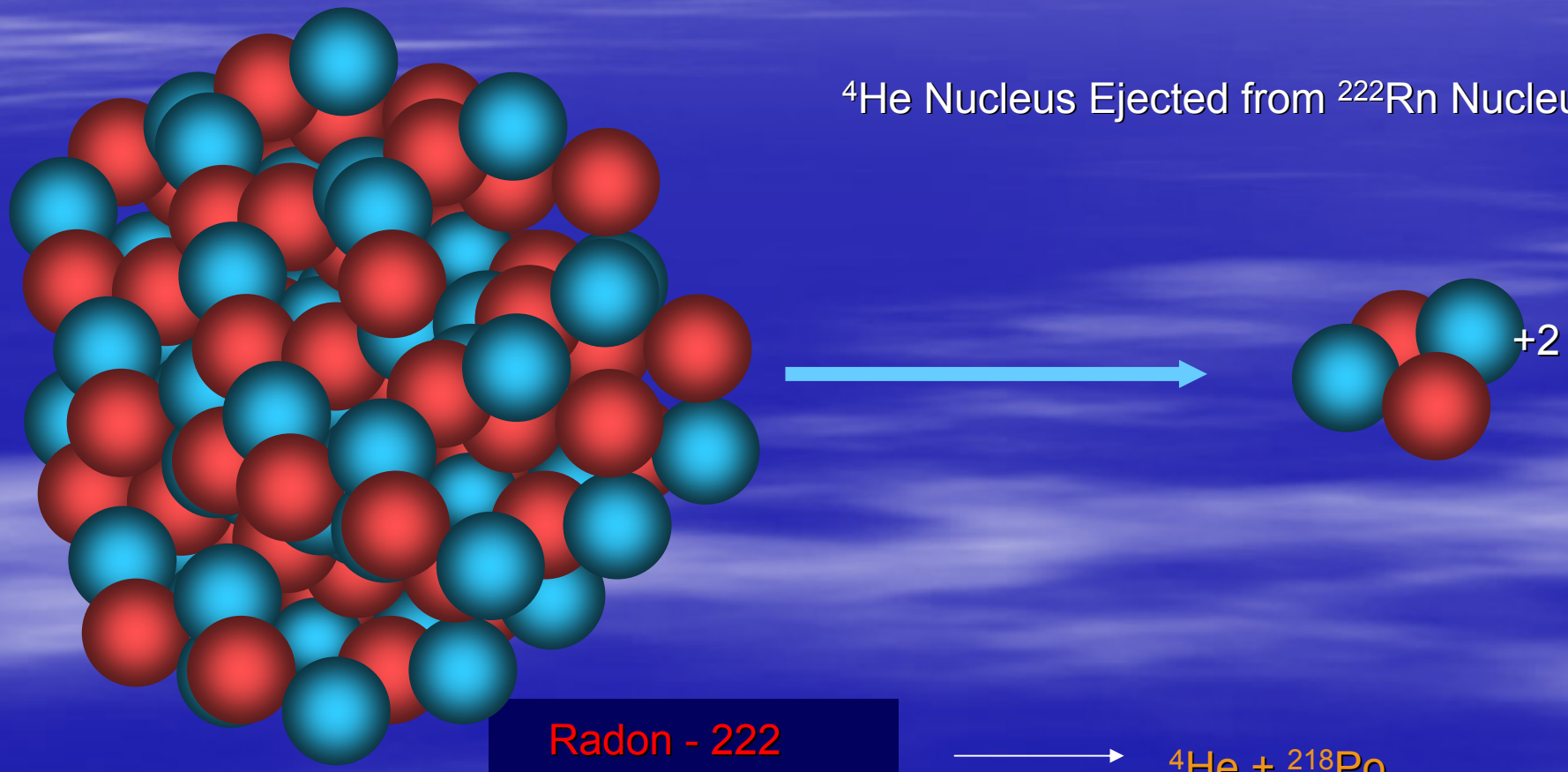
Why should we care?

Annual Effective Dose Equivalent to Member of the U.S. Population



Alpha Decay

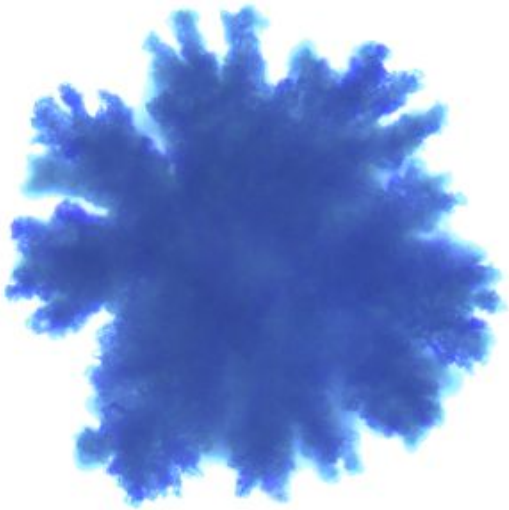
^{4}He Nucleus Ejected from ^{222}Rn Nucleus



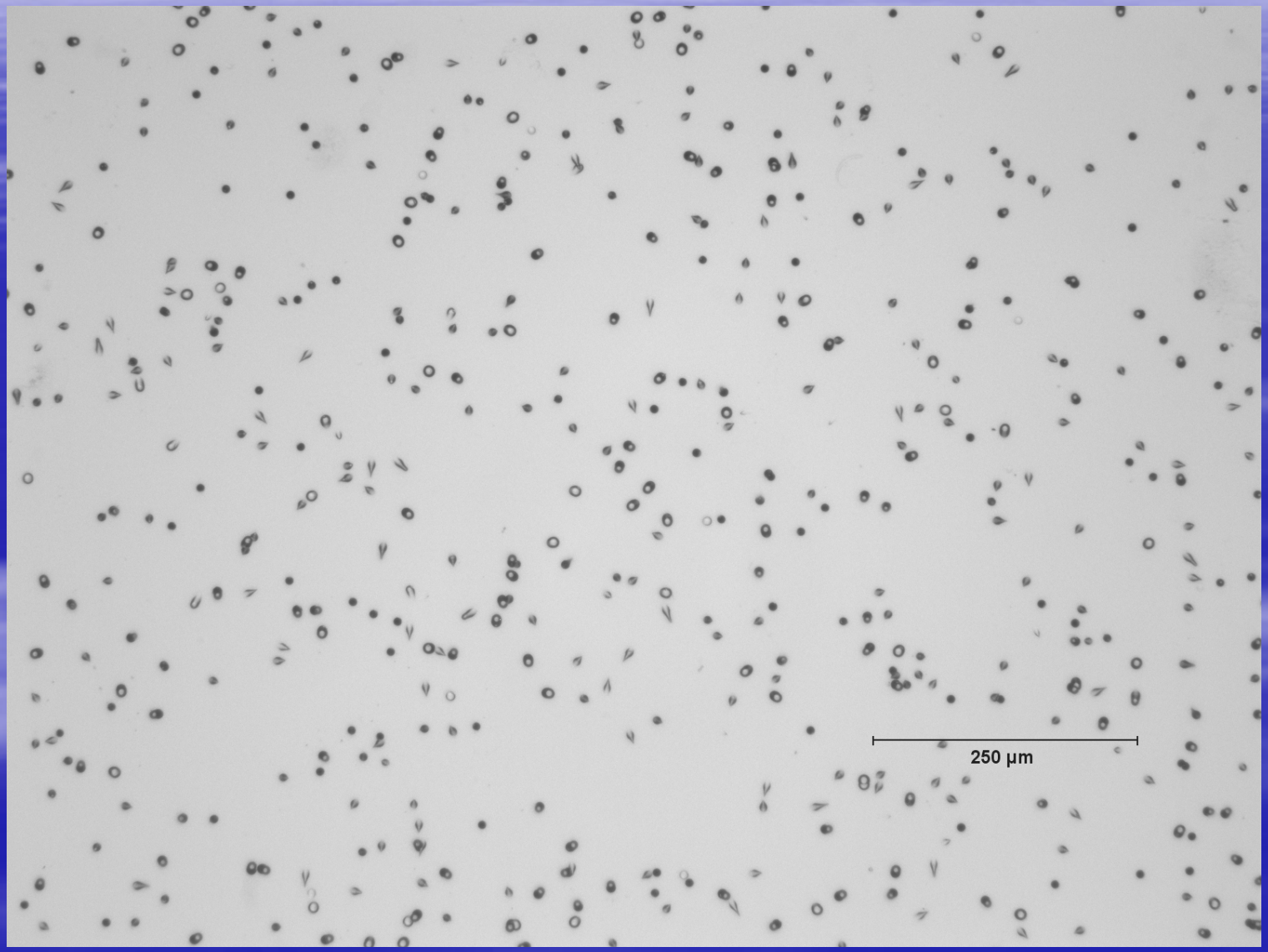
Radon - 222

$^{4}He + {}^{218}Po$

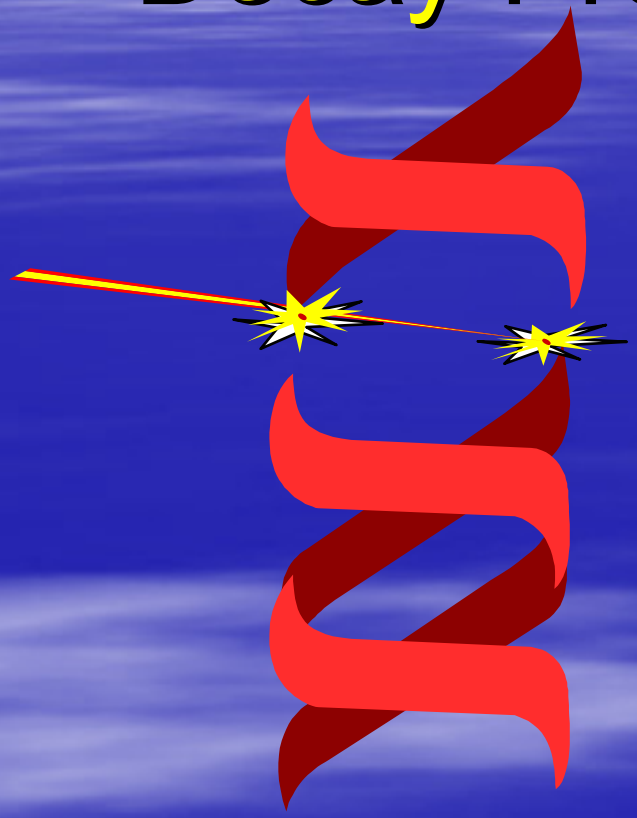
Alpha Particle Impact



Alpha Impacts in CR-39 plastic



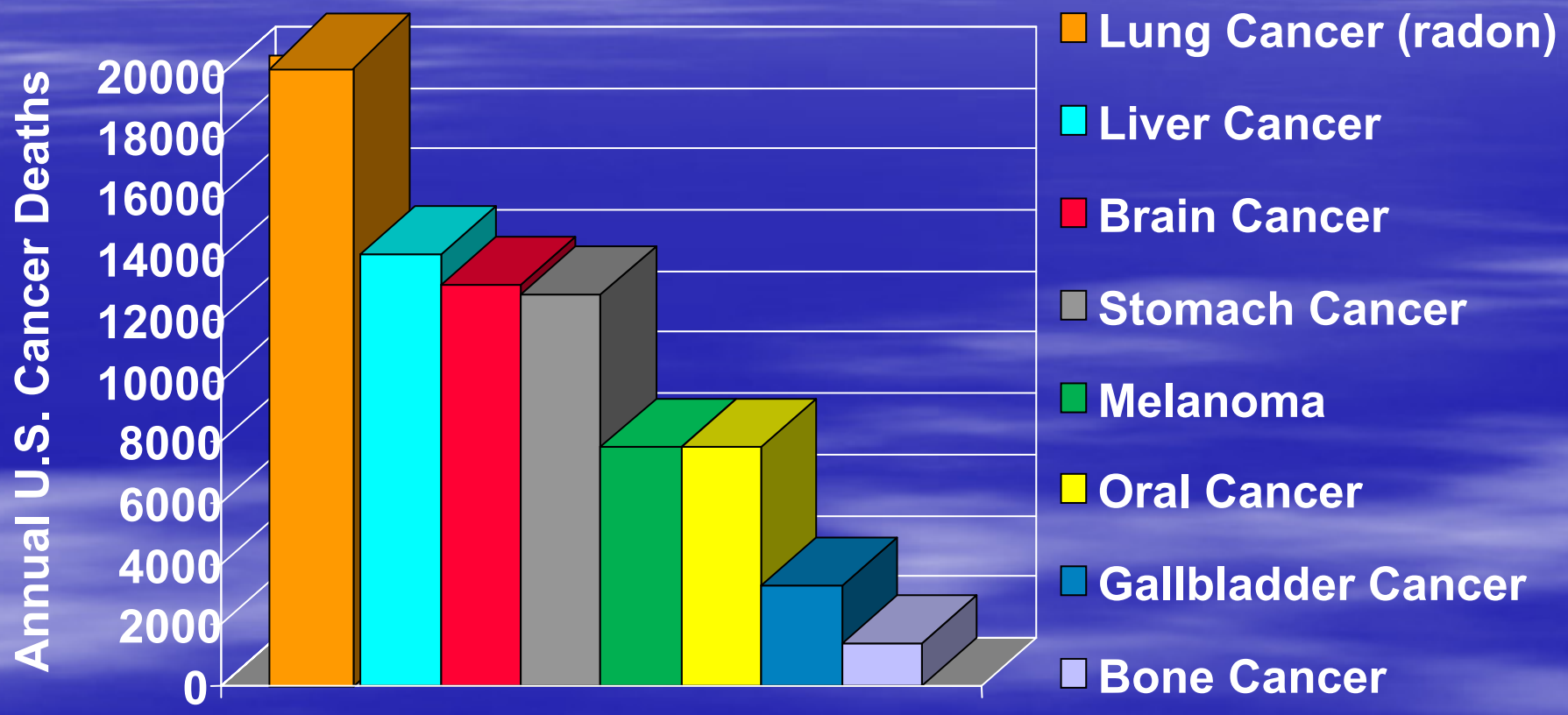
What Happens When Radon Decay Products Are Inhaled?



Double Strand Breaks

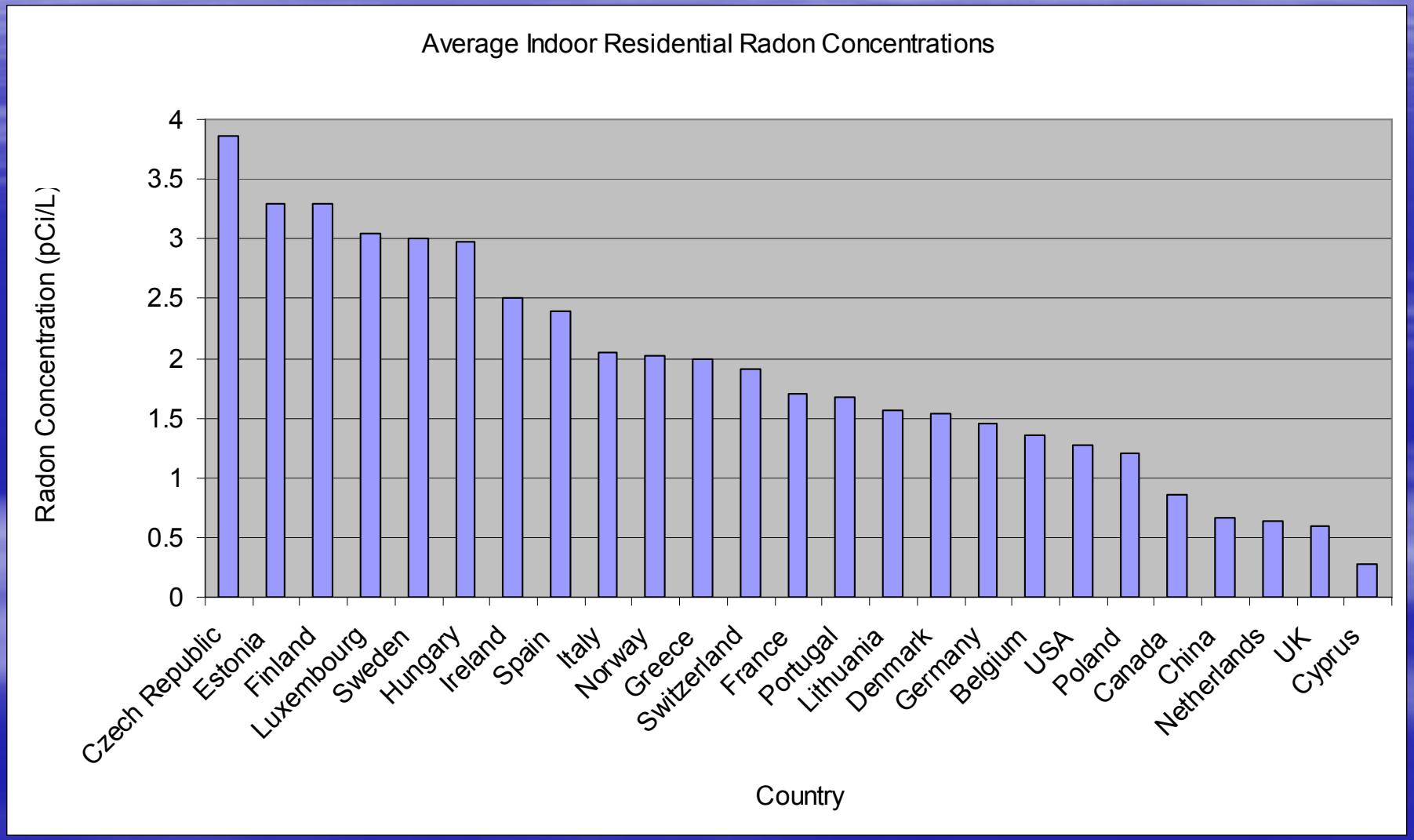
- Highly radioactive particles adhere to lung tissue, where they can irradiate sensitive cells.
- Radiation can alter the cells, increasing the potential for cancer.

Comparing Radon-Related Cancer to Other Types of Cancer



Not just in the US

Radon Around the World



World Health Organization

International Radon Project

Working Groups

Occurrence

Measurement

Mitigation

Exposure Guidelines

Global Disease Burden

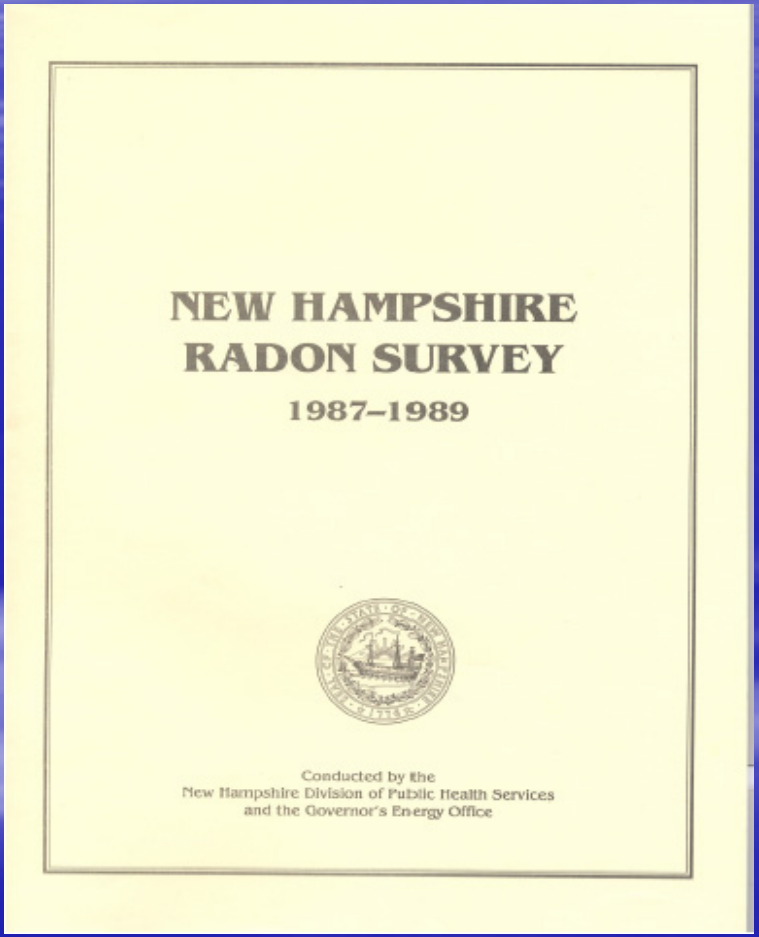
Canadian and European Guidance

- Range is 150 – 600 Bq m^{-3}
  - ~ 4 – 16 pCi/L
  - Generally, 200 Bq m^{-3}
  - 5.4 pCi/L

In the US

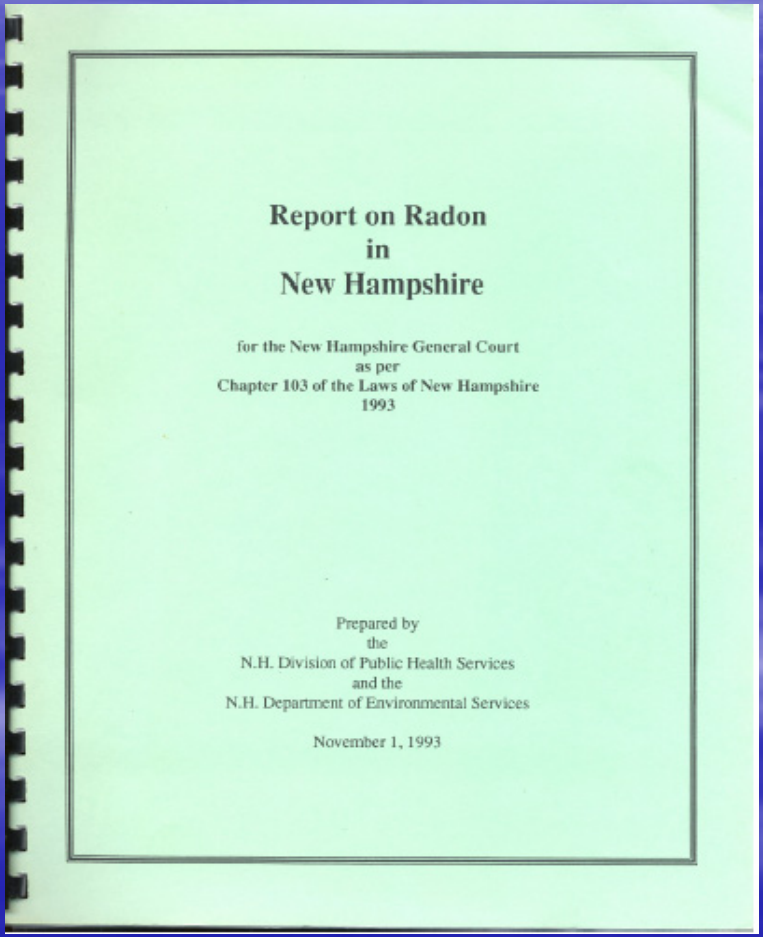
- 4 pCi/L USEPA Action Guideline
  - Technological
- National average
  - 1.25 pCi/L
- Annual Risk
  - >21,000 cancer deaths per year

Radon in New Hampshire



NEW HAMPSHIRE
RADON SURVEY
1987–1989

Conducted by the
New Hampshire Division of Public Health Services
and the Governor's Energy Office



Report on Radon
in
New Hampshire

for the New Hampshire General Court
as per
Chapter 103 of the Laws of New Hampshire
1993

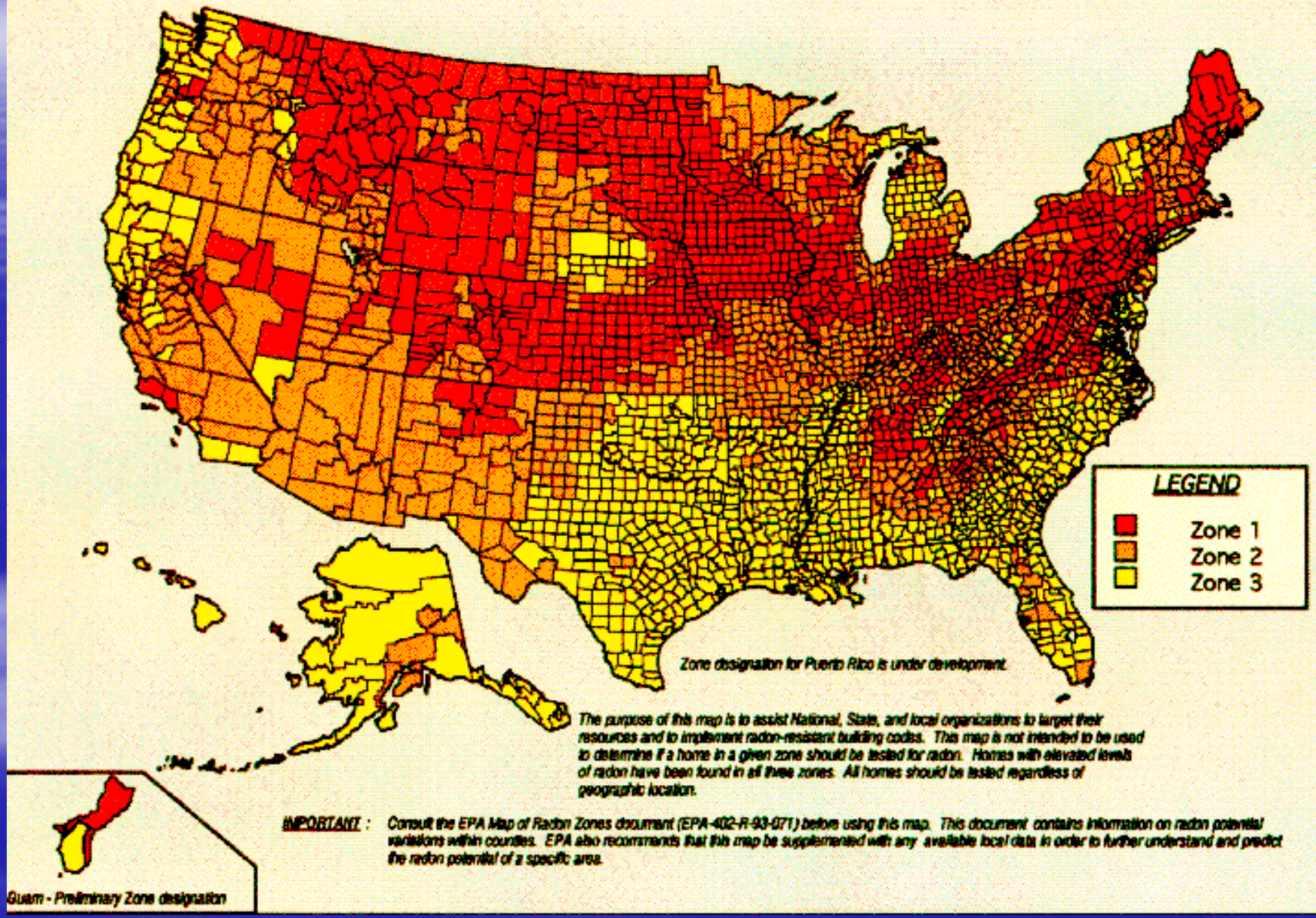
Prepared by
the
N.H. Division of Public Health Services
and the
N.H. Department of Environmental Services

November 1, 1993

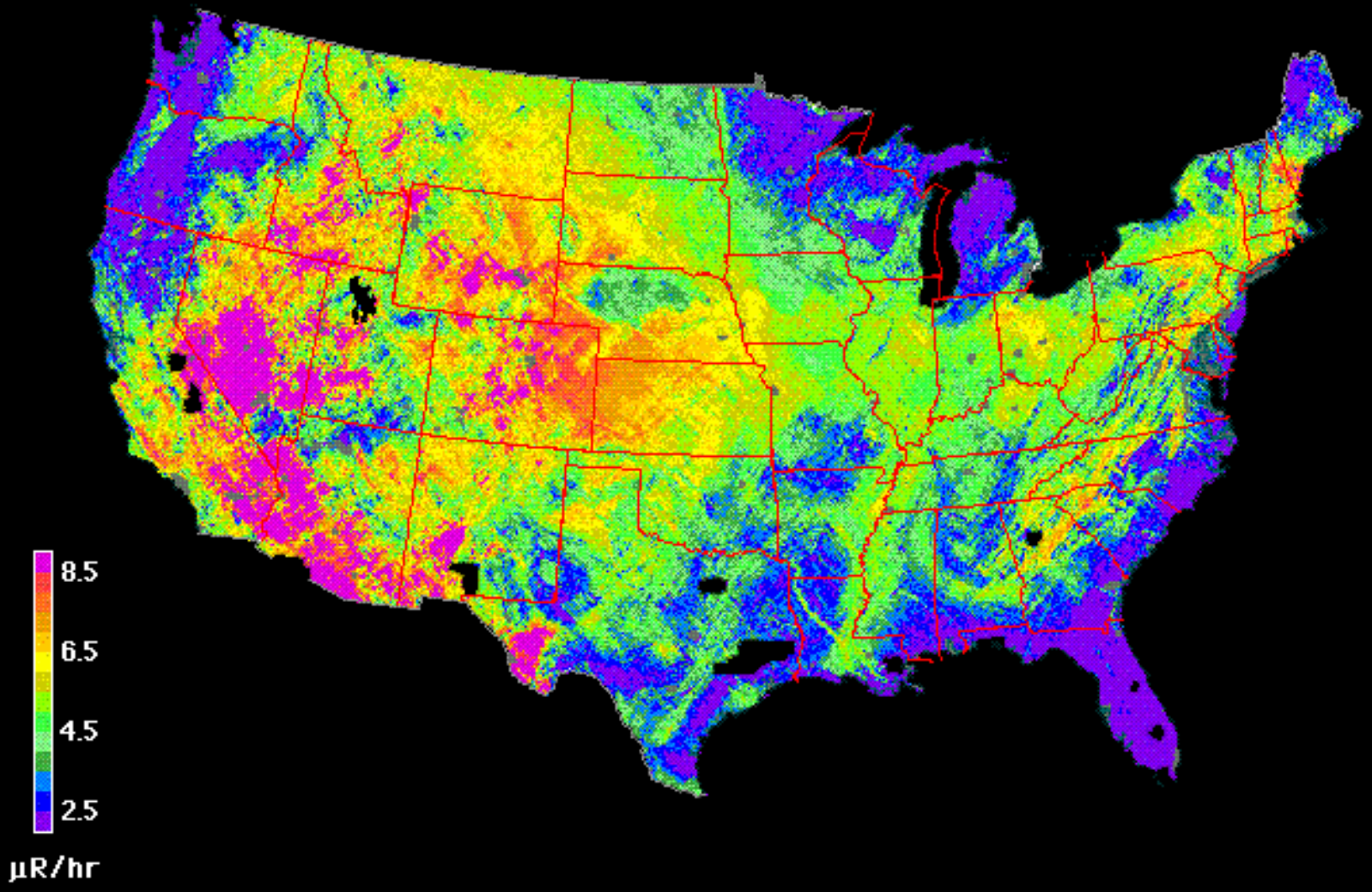
Rn Risk in NH

- Nationally:
  - 13 -14% of all lung cancer deaths
- In New Hampshire:
  - Approximately 100 deaths per year

EPA Map of Radon Zones

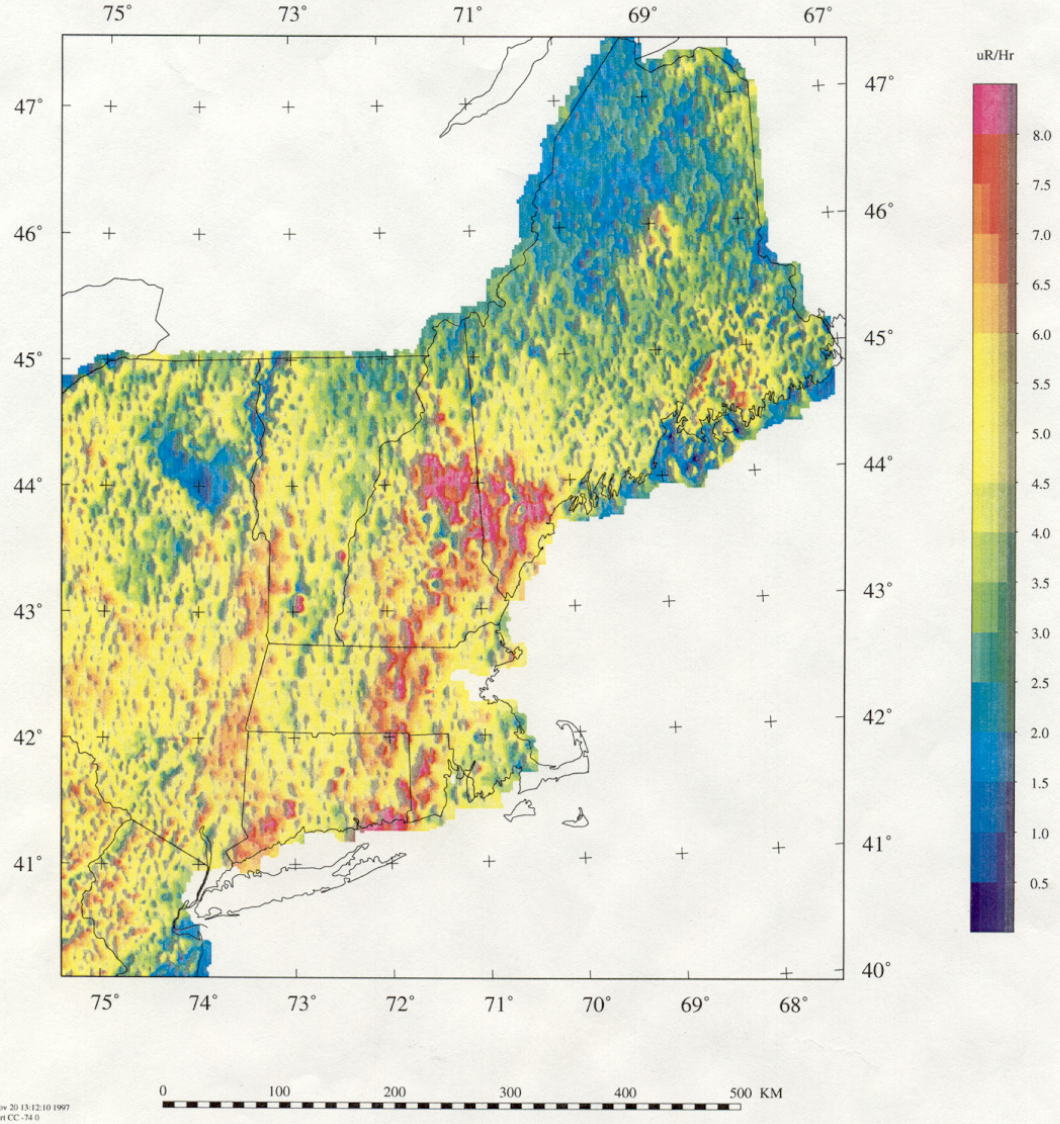


Terrestrial Gamma-Ray Exposure at 1m above ground



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

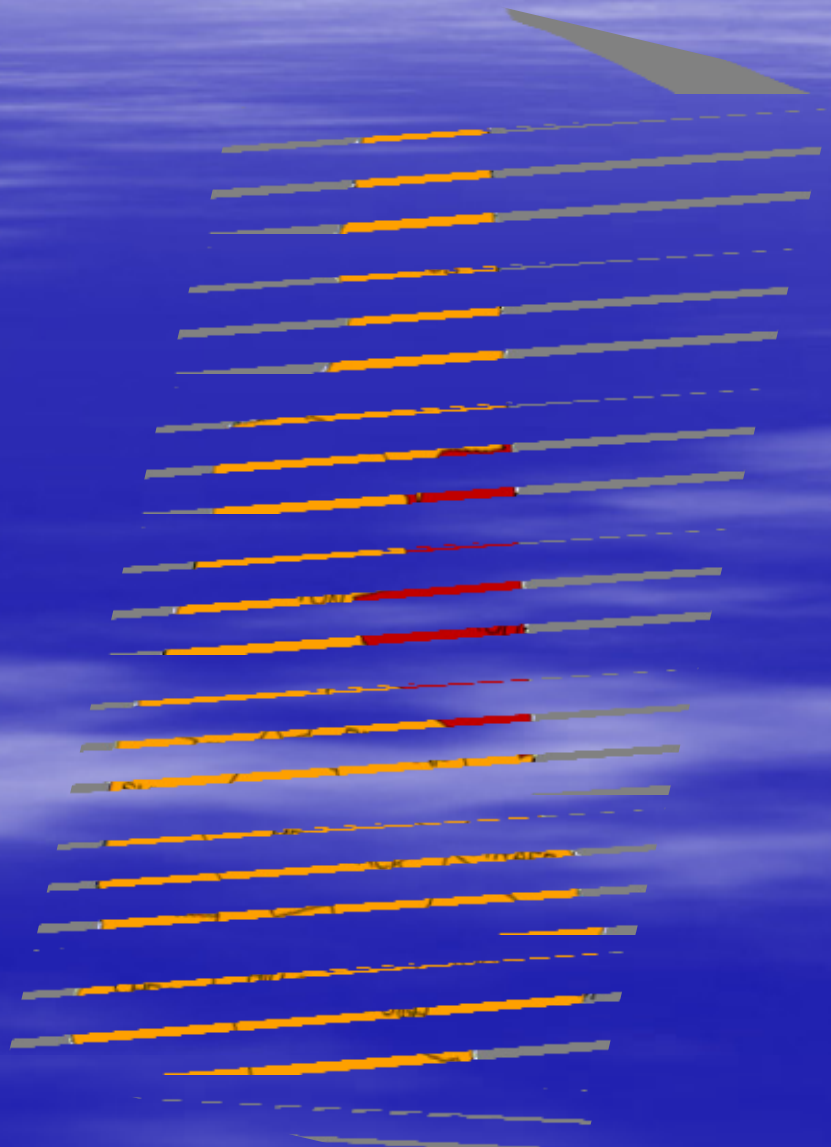
Terrestrial Gamma-ray Exposure



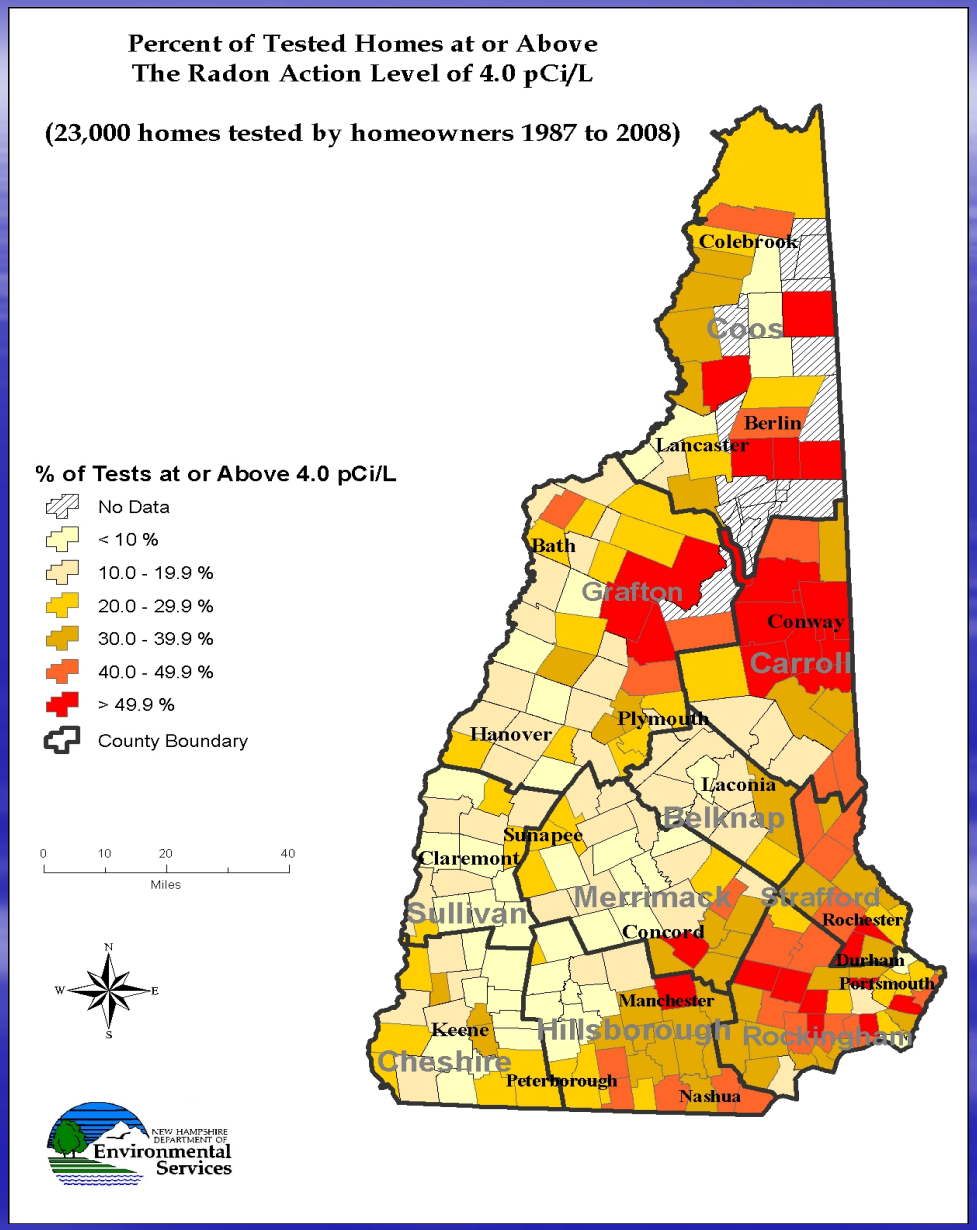
Thu Nov 20 13:12:10 1997
Lambert CC -74 0

EPA Map for NH

- Zone 1
- Zone 2
- Zone 3



Our Radon Map for NH



New Hampshire

The Granite State

SIMPLIFIED BEDROCK GEOLOGIC MAP OF NEW HAMPSHIRE

EXPLANATION

IGNEOUS ROCKS

TRIASSIC-CRETACEOUS (245 - 150 Ma*)
White Mountain plutonic and volcanic rocks (mostly granite, syenite, and rhyolite)

CARBONIFEROUS-PERMIAN (350 - 245)
Two-mica granite

DEVONIAN (410 - 350)
New Hampshire plutonic rocks
(a) Granite
(b) Granodiorite
(c) Diorite

SILURIAN (440 - 410)
Granite and granodiorite

ORDOVICIAN (500 - 440)
Highlandcroft and Oliverian granitic rocks

METAMORPHIC ROCKS

DEVONIAN (~400)
Slate, schist and quartzite, and gneiss

SILURIAN (~430)
Schist, quartzite, and minor carbonate rocks

CAMBRIAN-SILURIAN (520 - 430)
Rusty schist and metavolcanic rocks (w)
Impure and calcareous quartzite and slate(s)

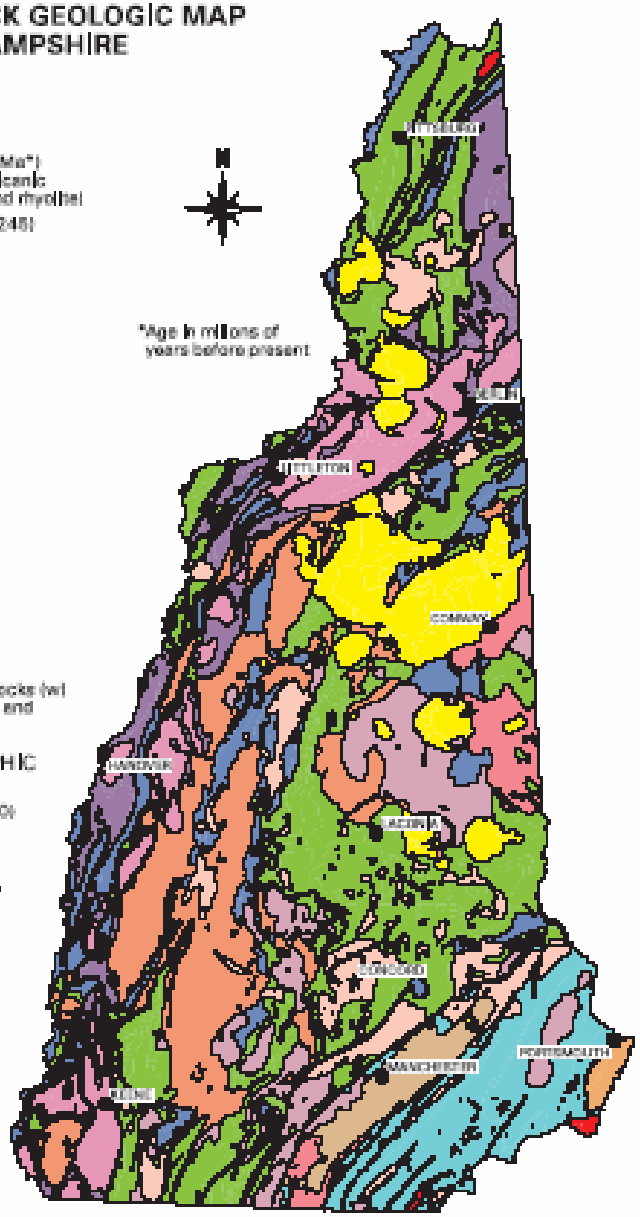
UNDIFFERENTIATED METAMORPHIC AND IGNEOUS ROCKS

PRECAMBRIAN-ORDOVICIAN (> 450)
Gneiss of the Massabesic (m) and fault rocks of the Rye complex (r), both contain igneous and metamorphic rocks.

FAULTS

CONTACTS

*Age in millions of years before present



Adapted from Lyons and others, 1997, Bedrock geologic map of New Hampshire: U.S. Geological Survey, Reston, VA, State Geologic Map, 2 sheets, scale 1:250,000 and 1:500,000, by W.A. Bothner and E.L. Boudette.

SCALE 1:1,250,000

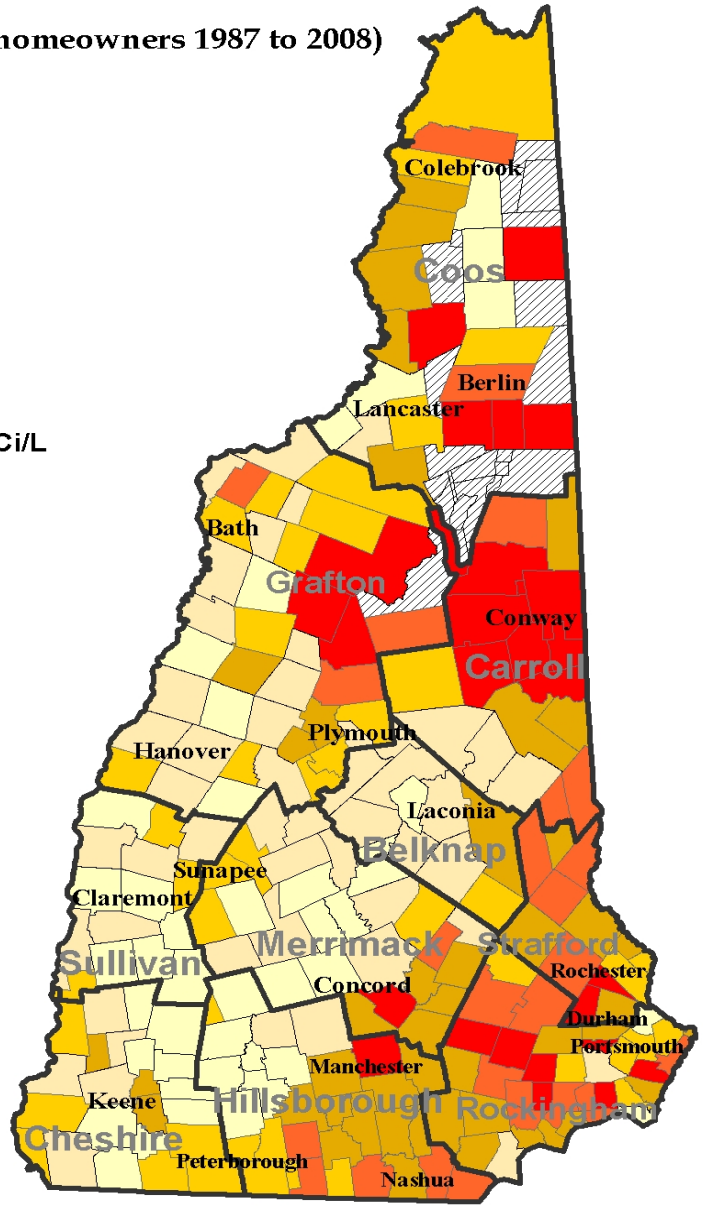
0 10 20 30 40 50 MILES

0 20 40 60 80 100 KM

Environmental Services

Percent of Tested Homes at or Above The Radon Action Level of 4.0 pCi/L

(23,000 homes tested by homeowners 1987 to 2008)



% of Tests at or Above 4.0 pCi/L

- No Data
- < 10 %
- 10.0 - 19.9 %
- 20.0 - 29.9 %
- 30.0 - 39.9 %
- 40.0 - 49.9 %
- > 49.9 %
- County Boundary

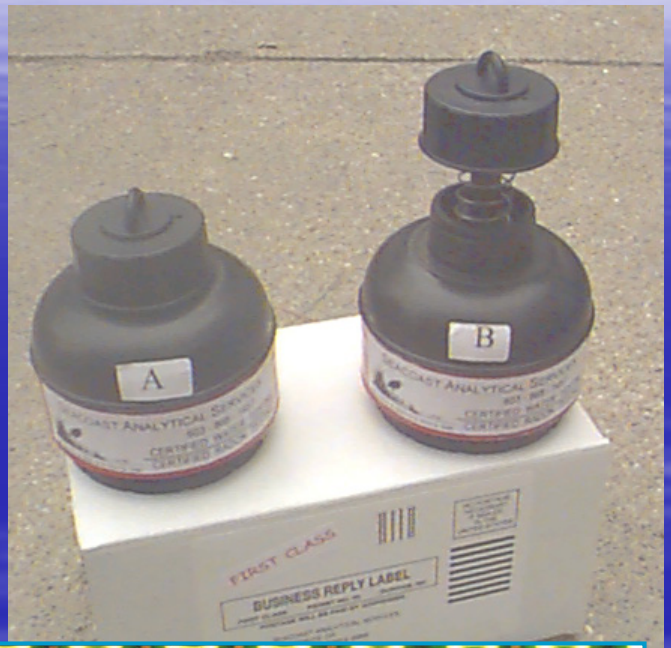
0 10 20 40
Miles

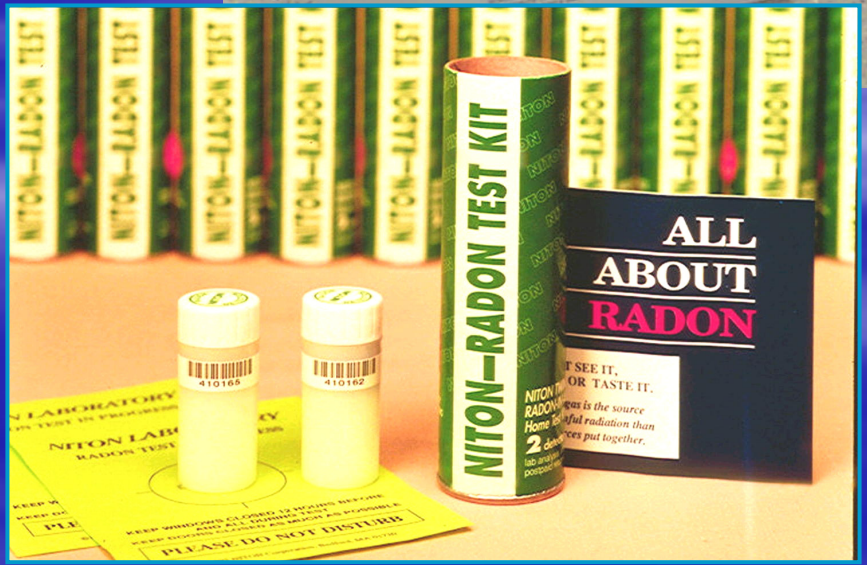
N W E S

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Testing

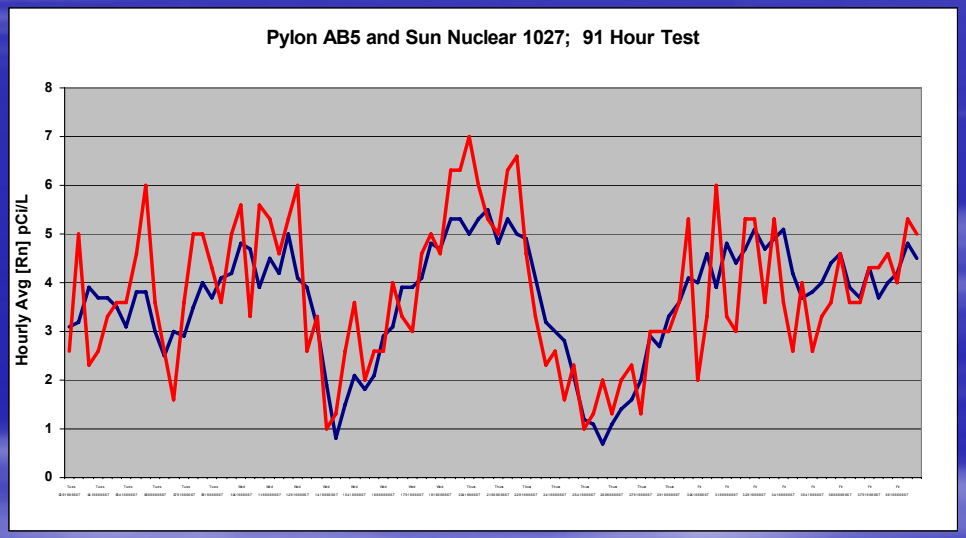
Test Devices



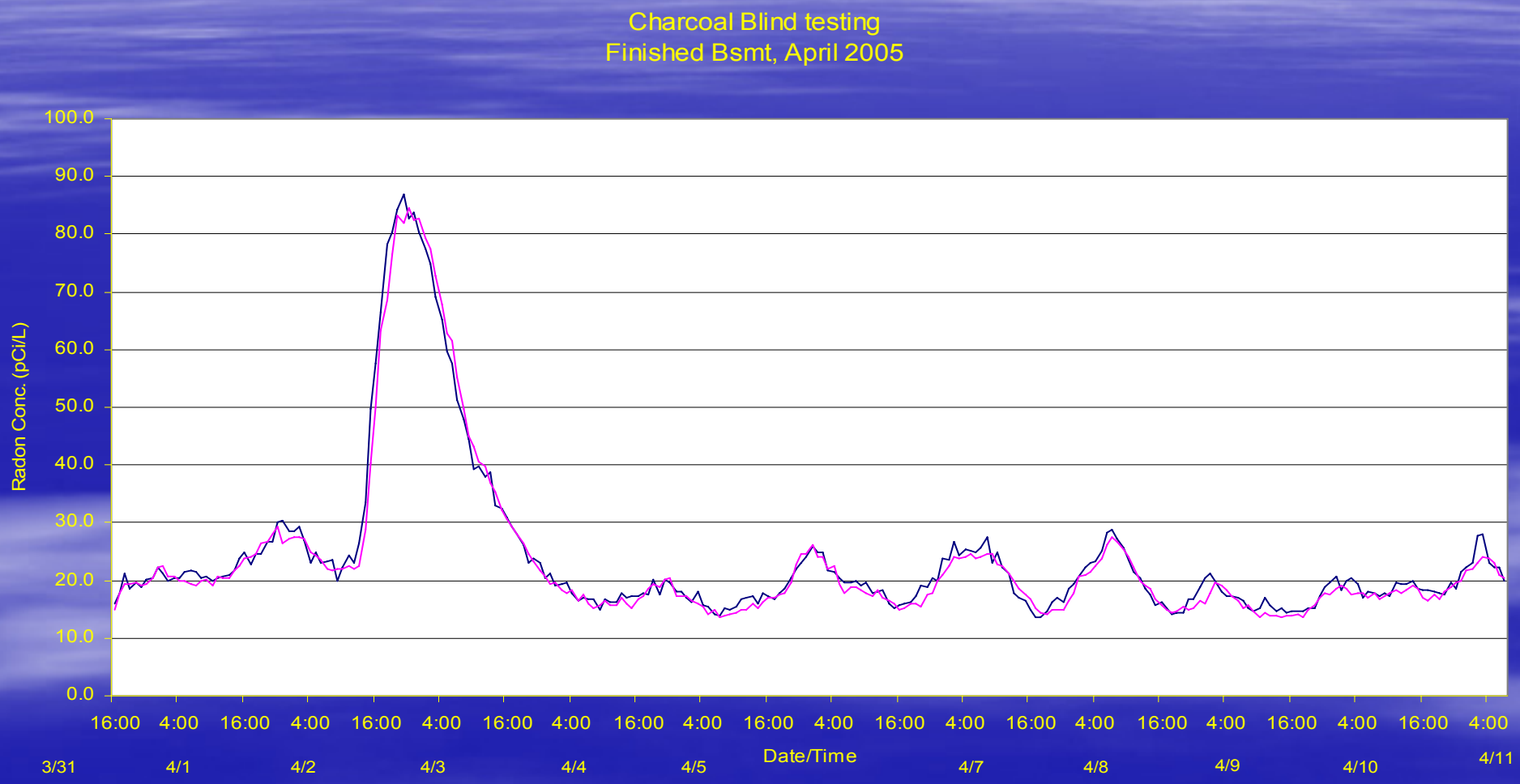


Continuous Radon Monitor

Measurement Sensitivity



Weather Effect



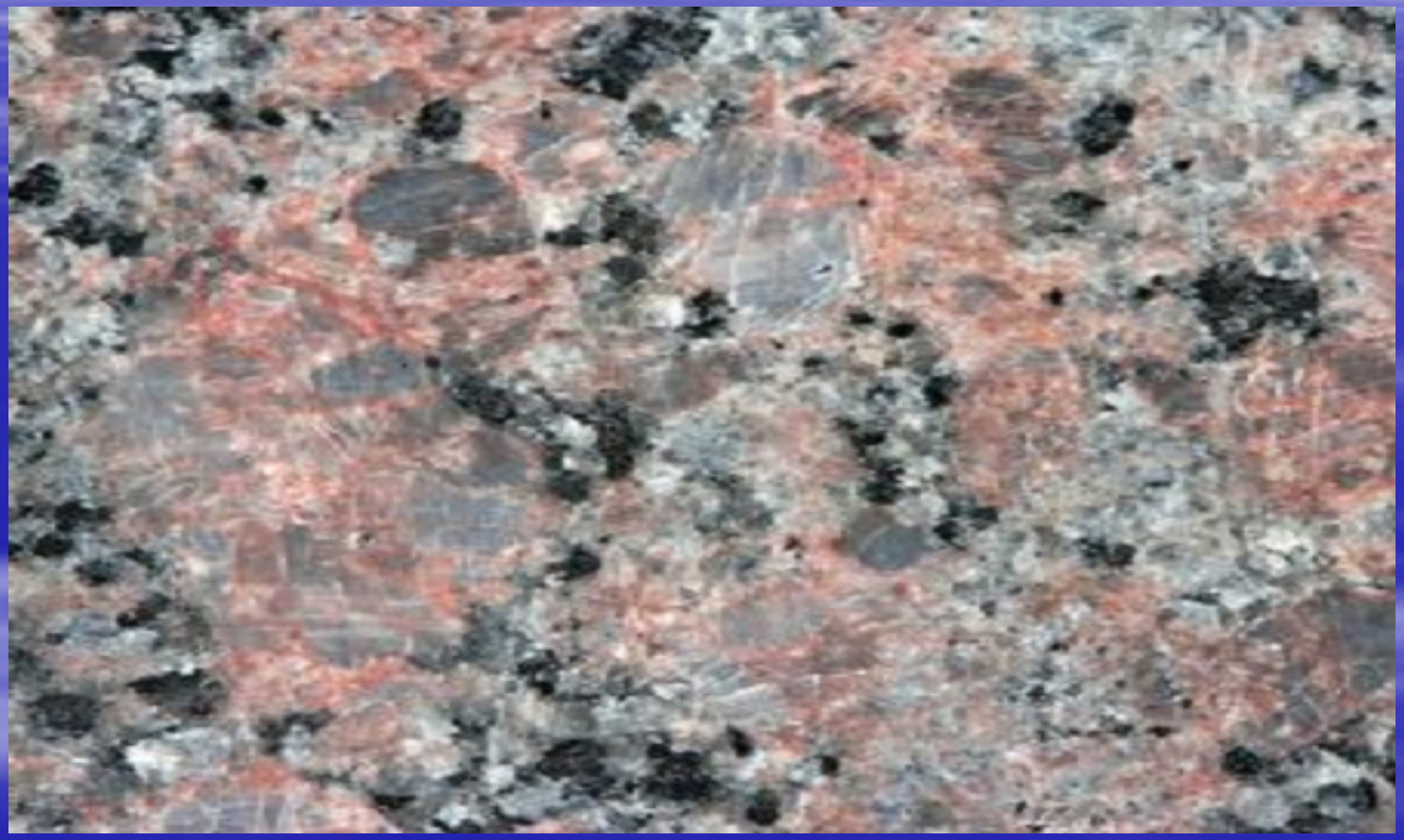
Testing Protocols (USEPA)

- Duplicate tests
- Minimum 48 hours
- Closed house conditions
- Radon Test Device Placement
  - lowest level of the home that could be used regularly, whether it is finished or unfinished. Conduct the test in any space that could be used by the buyer as a bedroom, play area, family room, den, exercise room, or workshop.
- Avoid particularly severe weather

Testing Protocols (USEPA)

- Low Traffic Room, away from drafts, away from extreme heat & high humidity, avoid from direct sunlight
- Not in kitchens, small closets, crawl spaces, or bathrooms
- At least 20” from floor
- If hung 6 to 8 feet from the floor
- More than 3 feet from exterior doors, windows, or other openings to the outside
- 12” or more from exterior walls
- At least 4” from other objects (such as another testing device)

Avoid Granite Counter Tops Can Interfere with Test Devices



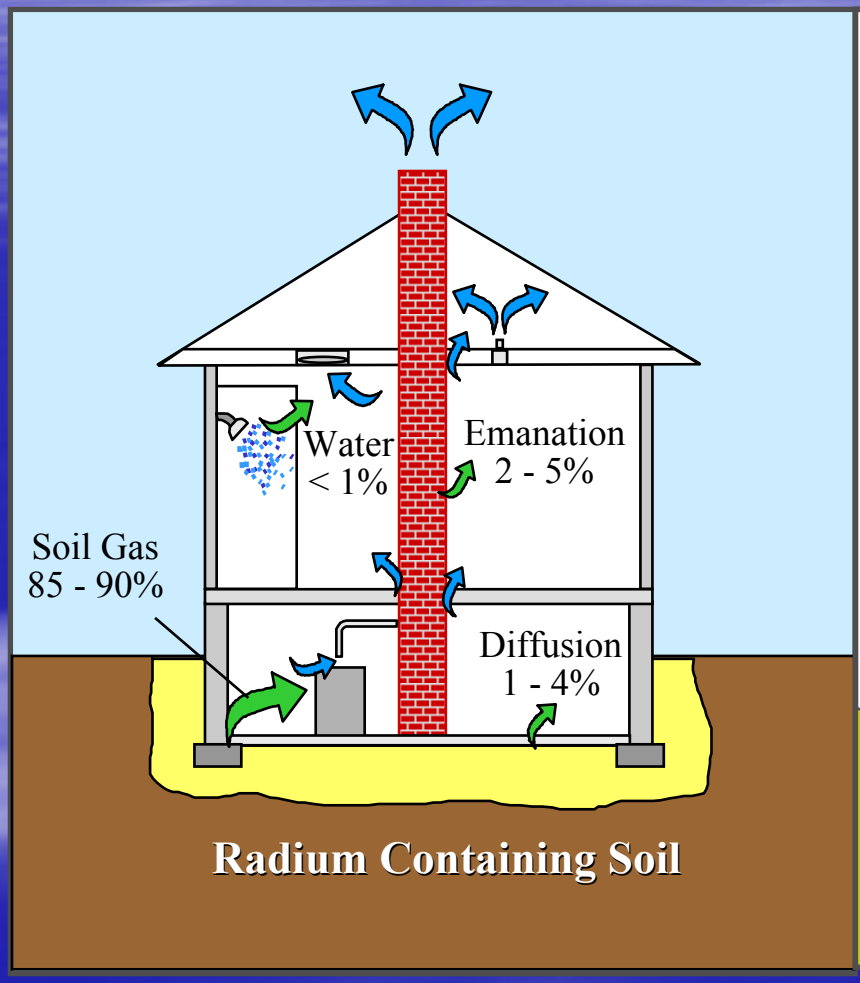
Radon Emanation from Natural Stone Products

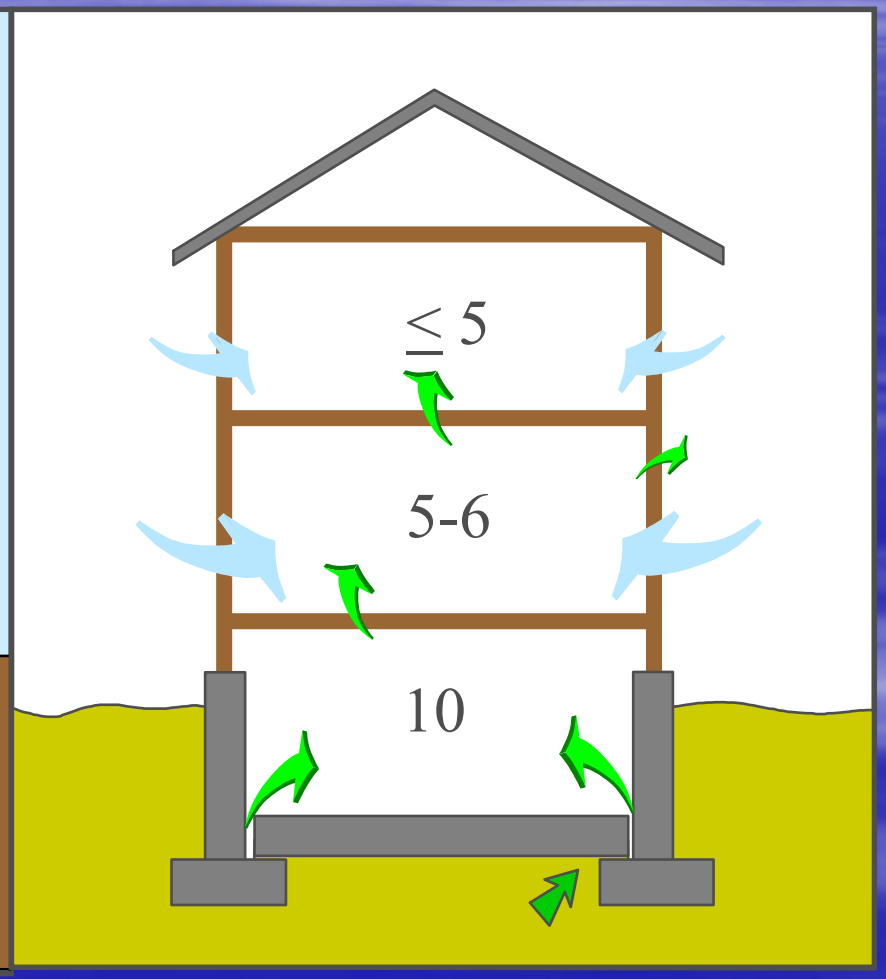
- Low risk potential compared to radon gas coming in under home or via water
- Other sources background radiation most often much higher
- Not just alpha radiation but beta and gamma as well
- Need specialized equipment to test
- Only certain granites are an issue
- Check these web sites for more information
- www.radongas.org/
- www.nrsb.org/
- www.epa.gov/iaq/index.html
- www.marble-institute.com/

Database short-term tests

- 23,717 results
- 7,359 results ≥ 4 pCi/L (31.0%)
  - 8% between 3.5 – 4.5 pCi/L
  - 16% between 3.0 – 5.0 pCi/L
- 2,480 results ≥ 10 pCi/L (10.5%)
- 940 results ≥ 20 pCi/L (4.0%)
- 45 results ≥ 100 pCi/L (0.2%)

Radon Entry

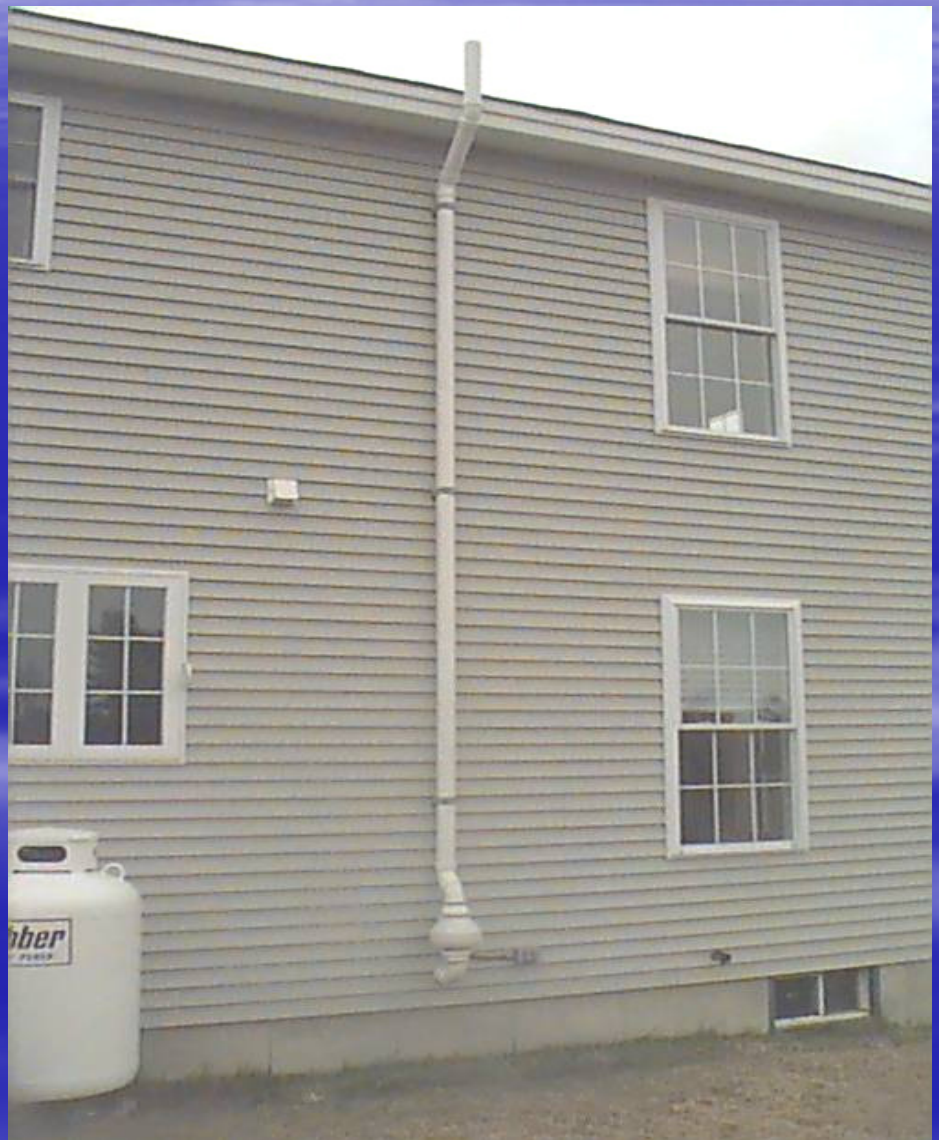

Water
< 1%
Emanation
2 - 5%
Soil Gas
85 - 90%
Diffusion
1 - 4%
Radium Containing Soil


≤ 5
5-6
10

Residential Radon Mitigation

- American Society for Testing and Materials
  - ASTM E 2121 – 03
    - Standard Practice for
      - Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings

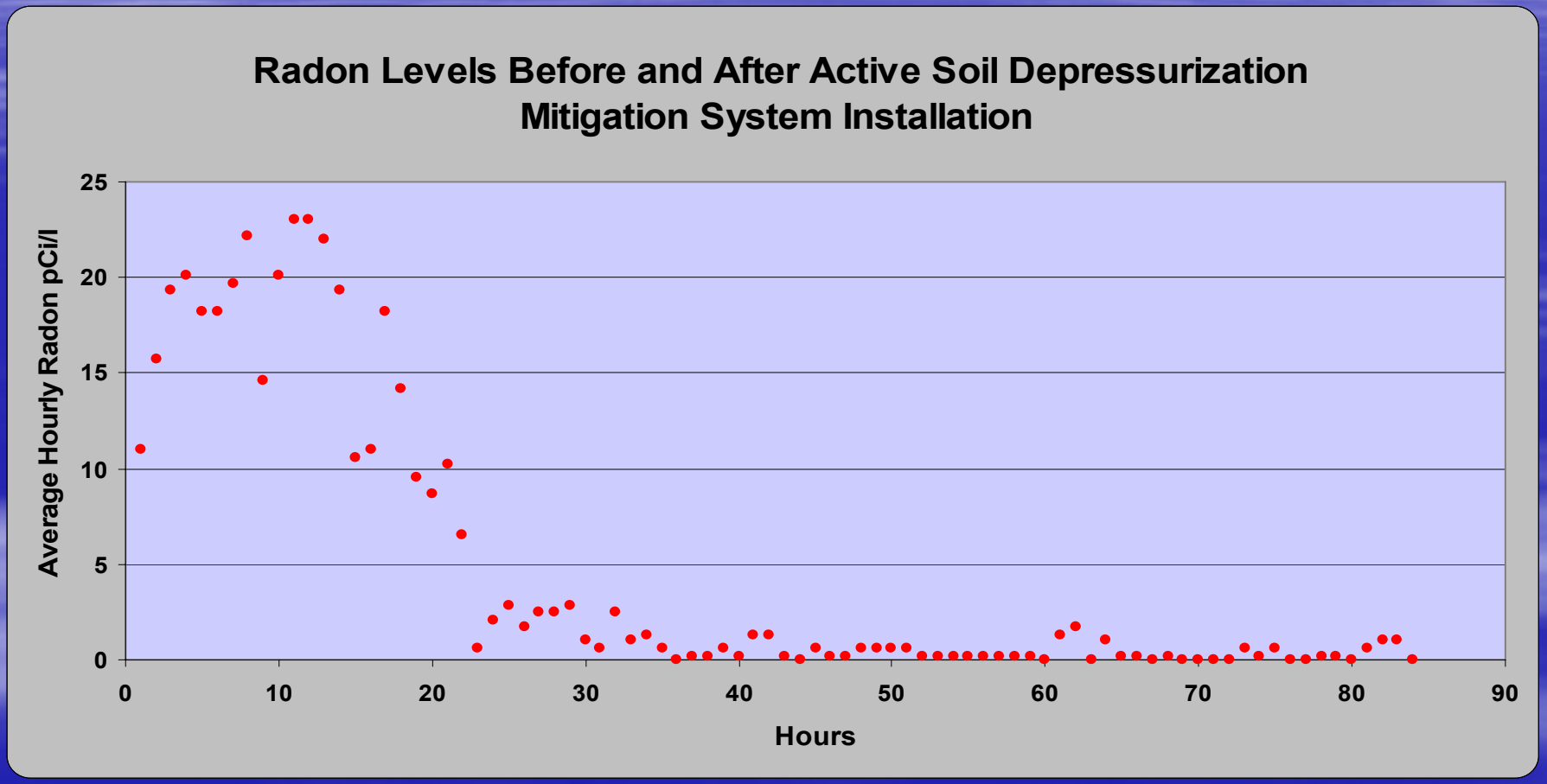
ASD Mitigation



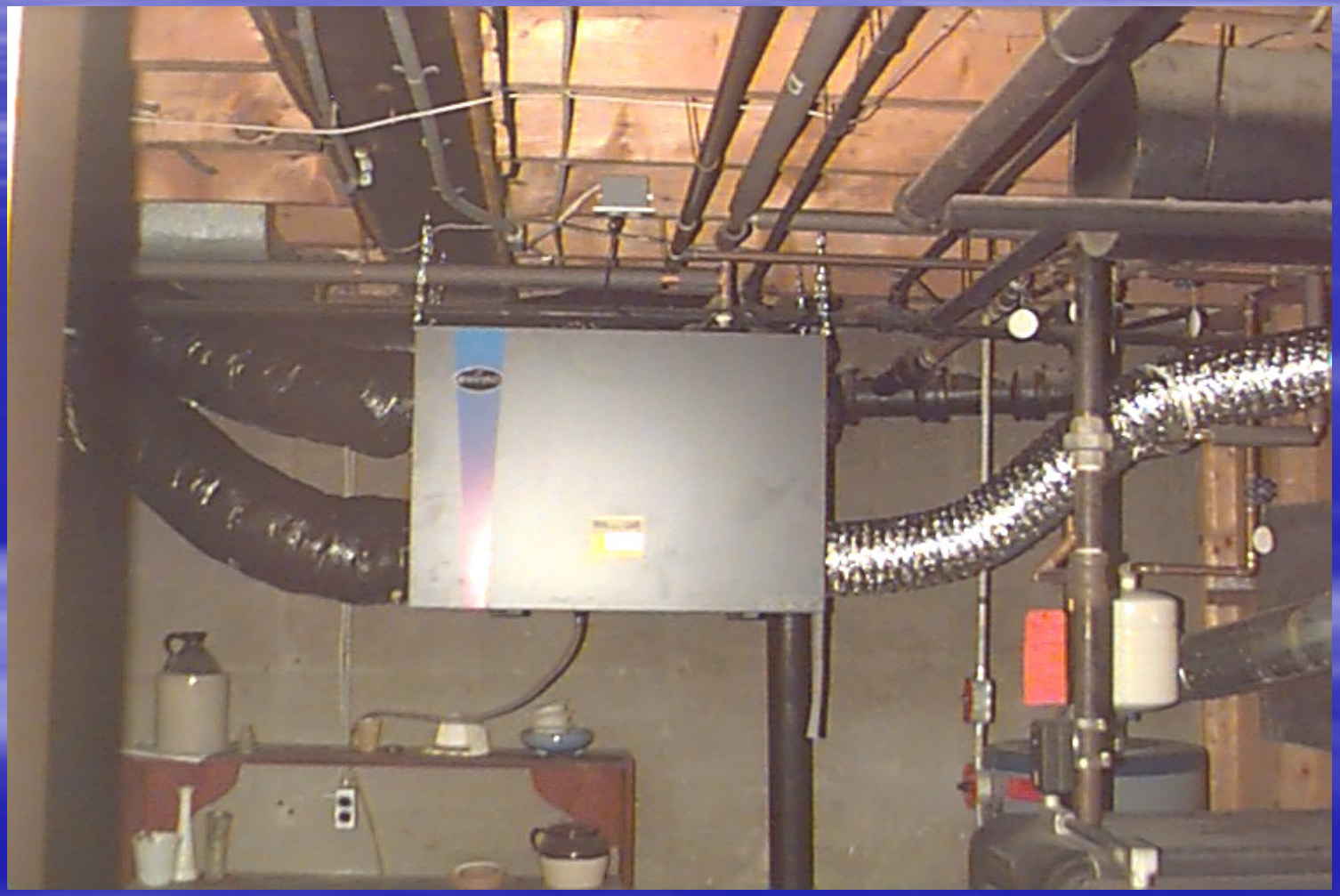
Mitigation Fan

U-tube Manometer

Effective Mitigation

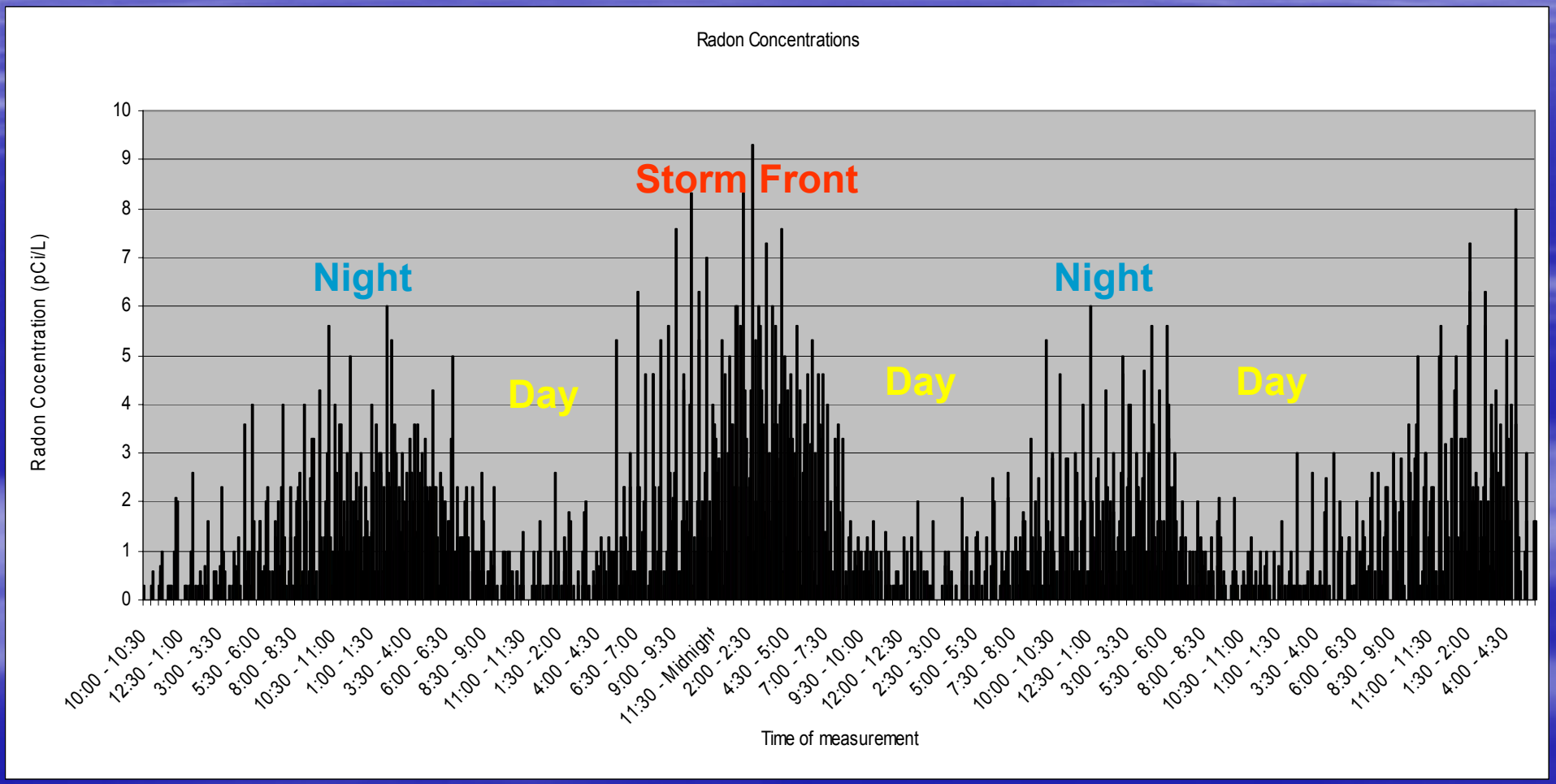


Heat Recovery Ventilator



HRV 6” outside vents

Large Buildings



Radon in water

Radon in Water

- History:
  - 1991 EPA publishes in Federal Register their view that radon must get down to 300 pCi/L to meet SDWA mandate
  - 1991 NH DES & DHHS comment; 2000 pCi/L works better for NH than 300 pCi/L
  - 1994 EPA proposes 300 pCi/L to Congress
  - 1996 Congress establishes 4000 pCi/L alternative MCL
  - 1998 National Academy of Science supports EPA risk estimates

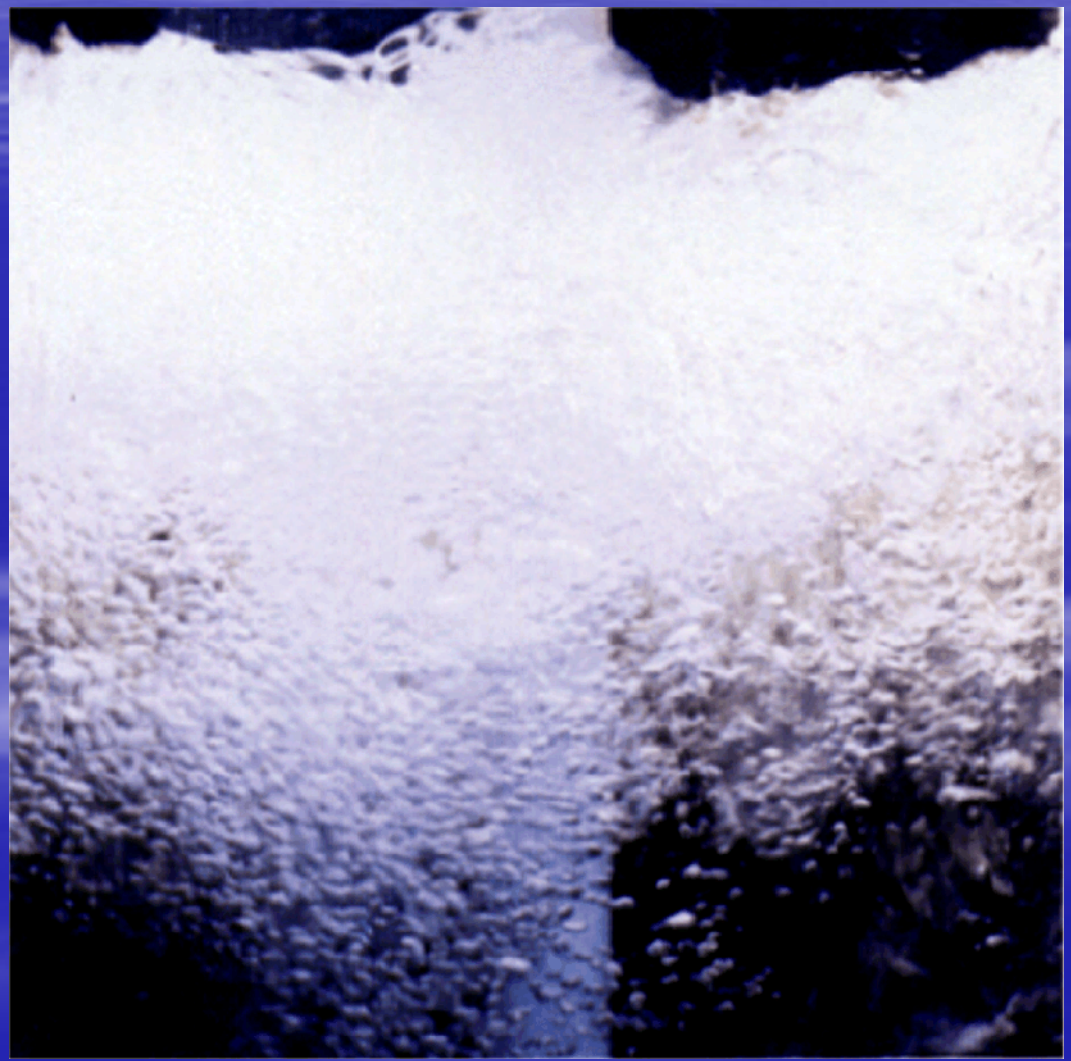
Current risk estimate

- Generally regulated as an ingestion risk
- 1 additional cancer / 10,000 people to
  1 additional cancer / million people.
- Radon in water has both ingestion risk (11%)
  and inhalation risk (89%).
- At 2000 pCi/L the combined risk is
  1 additional cancer / 1000 people.
- At 4000 pCi/L the ingestion risk alone is
  2 to 3 additional cancers / 10,000 people.

State Recommendations

- NH: 2,000 pCi/L
- ME: 4,000 pCi/L
- VT: 4,000 pCi/L
- RI: 4,000 pCi/L
- CT: 5,000 pCi/L
- MA: 10,000 pCi/L

Stripping Radon from Water



Radon Strippers

Why not carbon filtration?

Why not carbon filters

Uranium-238 Decay Series

NUCLIDE	SYMBOL	HALF-LIFE ($T_{1/2}$)	RADIATION RELEASED
Radon	^{222}Rn	3.823 Days	Alpha & Gamma
Polonium	^{218}Po	3.05 Minutes	Alpha & Beta
Lead	^{214}Pb	26.8 Minutes	Beta & Gamma
Bismuth	^{214}Bi	19.7 Minutes	Beta & Gamma
Polonium	^{214}Po	164 μSeconds	Alpha & Gamma
Lead	^{210}Pb	21 Years	Beta & Gamma

NH DHHS
Bureau of Radiological Health

- RSA 125-F:19 and He-P 4030.01
  - Essentially, it is illegal to possess, acquire, use, transport, dispose of, etc., sources of radiation without a license or as specifically exempted.

Best Decision Going Forward

- Radon Resistant New Construction
  - Permeable aggregate under the slab
  - Sealed gas impermeable vapor barrier / gas mat / perforated pipe
  - 3” or 4” PVC vent pipe
  - Straight vent pipe (few bends as possible)
  - Fan placement with wiring

Radon Resistant New Construction

- American Society for Testing and Materials
  - ASTM E 1465 – 07a
    - Standard Practice for
      - Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings

Resources for Information on Radon

- NH Radon Program Web Site

  www.des.nh.gov/organization/divisions/air/pehb/ehs/radon/index.htm
- USEPA Region 1 Radon Website

  www.epa.gov/region1/topics/pollutants/radon.html
- American Association of Radon Scientists and Technologists

  www.aarst.org/
- "Health Effects of Exposure to Radon BEIR VI" Board on Radiation Effects Research, Commission on Life Sciences. National Research Council. National Academy Press, Washington, D.C. 1999 (Book)
- World Health Organization International Radon Project

  www.who.int/ionizing_radiation/env/radon/en/

Who To Call

- Radon measurement and mitigation in the air:
  - www.radongas.org
  - www.nrsb.org
- Mitigation of radon in water:
  - www.des.nh.gov and search for fact sheet: dwgb-3-12
- NH Radon Program:
  - (603) 271-6845 Owen David
- Disposal of Activated Carbon Filters:
  - (603) 271-4840 Twila Kenna
- EPA Radon Publications:
  - www.epa.gov/iaq/radon/pubs