Lectures 22-23
Uranium and Radon

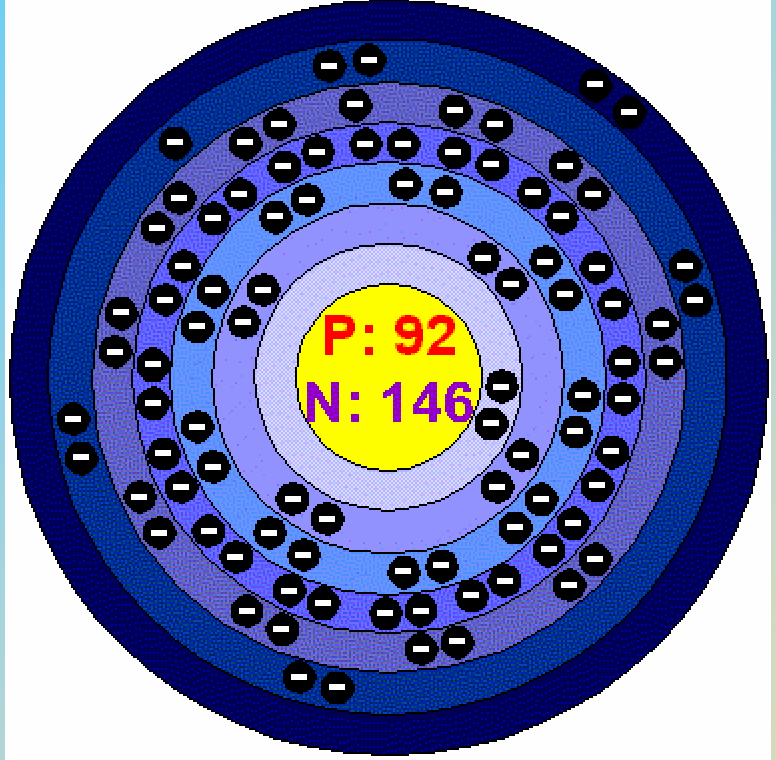
<u>Uranium Series</u>

- Isotopic production from decay of U,Th
  - can have natural activity which exceeds limits set by federal agencies.
  - 0.1 -4 ppb in groundwater as high as 100ppb
- exists no diminishable level for U - EPA proposed 20ppb (Canada- 100ppb)

* everything (as measurable radioactivity) is hazardous by nature.

Dominant isotope of U is ^{238}U (99.2%)

- is parent of all other U isotopes.
- is a major alpha emitter.
- $t_{½}$ = 4.47 GA
- $^{238}U = 1.55 \times 10^{-10} yr^{-1}$ (decay rate).

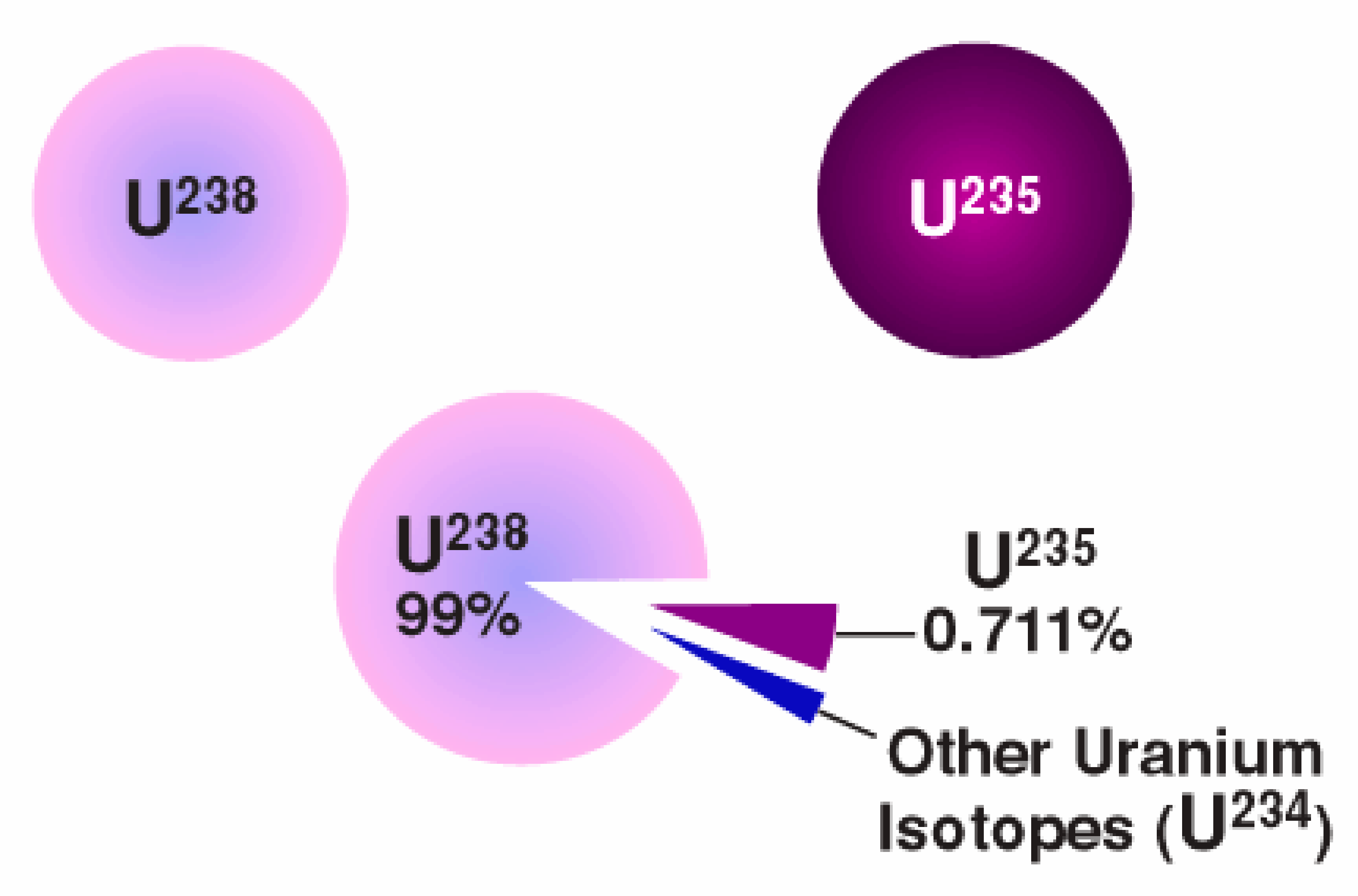


Number of Energy Levels: 7

First Energy Level: 2
Second Energy Level: 8
Third Energy Level: 18
Fourth Energy Level: 32
Fifth Energy Level: 21
Sixth Energy Level: 9
Seventh Energy Level: 2

http://www.chemicalelements.com/elements/u.html

Natural uranium contains 99 percent U-238 and only about 0.7 percent U-235 by weight.



http://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html

The Uranium-238 decay series; α denotes alpha decay, β denotes beta decay.

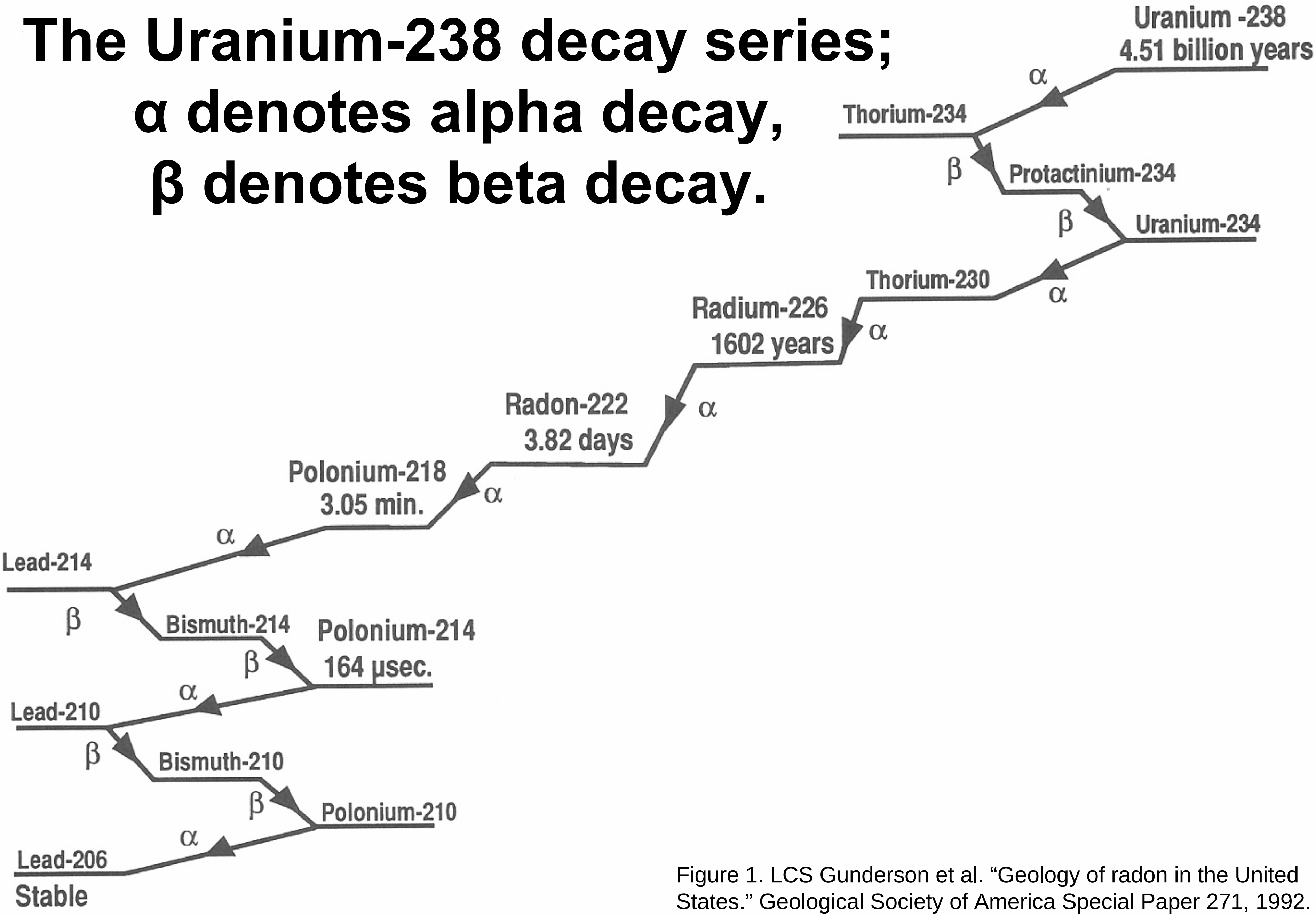


Figure 1. LCS Gunderson et al. "Geology of radon in the United States." Geological Society of America Special Paper 271, 1992.

- Since the earth has formed, about half of all the ^{238}U has decayed.
- $[^{238}U]$ = 20 ppb for the whole earth, but is concentrated in the crust.

  (Higher at radius, heavy, not miscible with iron)

- Therefore, the crustal concentration of U is about 2 ppm (U is mobile, therefore there are large variations).

* Concentrated in the crust because U^{6+} & U^{4+} are highly charged, have large atomic radii → melting concentrates U
  - Black shales concentrate U due to changes in redox condition → 100 ppm.
  - U is soluble in oxygenated water (as $UO_2^{(2+)}$ and as carbonate and hydroxy complexes) , not soluble in reducing conditions as U^{4+} .

	U abundance (ppm)	Pb abundance (ppm)	U/Pb ratio
Meteorites	0.008	2.470	0.003
Primitive mantle	0.021	0.185	0.113
Continental crust	1.4	12.6	0.111

The figure given for the continental crust is an average of the entire crust. Of course, local concentration of uranium can far exceed these values, ranging up to 50 ppm disseminated in some granites, to much higher values in ore deposits. In fact, in the geological past, local concentrations of uranium have occasionally achieved natural criticality, for example the Oklo reactors in Gabon.

http://world-nuclear.org/info/inf78.htm

^{235}U

- also occurs naturally in small quantities; useful b/c it fissions
- present day: $^{238}U/^{235}U = 138/1 = N_{238}/N_{235}$
- $^{235}U \rightarrow t_{1/2} = 700$ Ma (That's why there is so much less).
- **^{235}U -alpha decay → ^{207}Pb; ^{238}U -alpha, beta decay → ^{206}Pb.**

Companion Decay Series:

- ^{235}U, ^{232}Th → Don't produce nuclides, which are useful tracers for geologic/ environmental processes.
- ^{235}U used in fission bombs because it splits apart more readily than ^{238}U.
- a method to enrich ^{235}U ratio from 1% to 6%, enables manufacture of nuclear weapons (method is gaseous diffusion; ie. Paducah, KY).

→

Uranium goes through a series of gamma and beta decays

^{238}U -alpha beta decay → ^{206}Pb.

Alpha (α) = 2p, 2n → ^{4}He.

Beta (β–) = e-

– therefore, ^{4}He is a decay product (will sniff ^{4}He while prospecting for U).

Dating technique: $^{206}Pb/^{238}U$ coupled with ^{235}U.

- In the oceans, U is stable and Th is rapidly removed into sediments.

$^{230}Th = 0$; $^{232}Th = 0$ → $^{230}Th = {}^{230}Th_o e^{-\lambda t}$

→ $t = (-1/\lambda) \ln (^{230}Th/^{230}Th_o)$

- In corals, look at ^{234}U → ^{230}Th :

* ^{230}Th chronometer of choice to establish age of corals.

^{234}U useful in age dating of old water.

** Calibration curve relation allows for pretty good estimates up to 100 kyr

→ ^{234}U & ^{230}Th & ^{14}C age versus age reflect climatic conditions

URANIUM SERIES:

^{238}U → ^{234}Th → ^{234}U → ^{230}Th →

α, $t_{1/2}$ = 4.47Ga β, $t_{1/2}$ = 24 days α, $t_{1/2}$ = 244,000 yr $t_{1/2}$ = 77,000yr

^{226}Ra → ^{222}Rn → ^{218}Po → ^{214}Pb

$t_{1/2}$ = 1600y α, $t_{1/2}$ =3.8 days

- ^{234}Th : refractory, insoluble in water.
- ^{234}U : stable, U $O2^{++}$.
- ^{226}Ra : alkaline earth, highly mobile, highly soluble in water.
- ^{222}Rn : noble gas, volatile, doesn't react, highly mobile (causes problems).
- ^{218}Po : heavy metal.

→ limited by decay, better off if can be measured directly in mass spec.

Isotope	Half Life
U-230	20.8 days
U-231	4.2 days
U-232	70.0 years
U-233	159000.0 years
U-234	247000.0 years
U-235	7.0004E8 years
U-236	2.34E7 years
U-237	6.75 days
U-238	4.47E9 years
U-239	23.5 minutes
U-240	14.1 hours

http://www.chemicalelements.com/elements/u.html

Rule:

- If $t_{1/2} > 1000$ years, use mass spec.
- If $t_{1/2} < 100$ years, count it.

Activity (rate of change):

$A = dN/dt = \lambda N$

λ = decay constant

N = number of atoms

SI unit = Bequerel (Bq)

1 Bq = dps/g = decays per second/gram.

→ Ci = 3.7×10^{10} decays/sec

pCi = 0.03Bq

i.e. ^{226}Ra, count it and measure it.

What is this useful for?

Bateman Equations:

$$N_1 \xrightarrow{\lambda_1} N_2 \xrightarrow{\lambda_2} N_3$$

How do N_1 & N_2 compare?

Activity: $A_1 = dN_1/dt \quad = -\lambda_1 N_1$

$A_2 = dN_2/dt \quad = (N_1\lambda_1 - N_2\lambda_2)$

→ This is a differential equation radioactive decay equation.

$N_1 = N°_1 e^{-\lambda_1 t}$

($A_1 = -\lambda_1 \underline{N}_1$; $N°_1$ = amount originally present)

$\underline{(dN_2 /dt)^*} + \lambda_2 N_2 - \lambda_1 N°_1 e^{-\lambda_1 t} = 0$

$N_2 = [\lambda_1 / (\lambda_2 - \lambda_1)] (N°_1) (e^{-\lambda_1 t} - e^{-\lambda_2 t}) + N°_2 e^{-\lambda_2 t}$

(initial daughter)

If $\lambda_2 >> \lambda_1$ (long-lived parent)

ie. $\lambda(^{234}Th) >> \lambda(^{238}U)$

→ **This is secular equilibrium if this occurs.**

then $N_2 = \dfrac{(\lambda_1)}{(\lambda_2 - \lambda_1)} N^o_1 e^{-\lambda_1 t}$

→ $N_2 = \lambda_1 N_1 / (\lambda_2 - \lambda_1)$

and $\lambda_2 N_2 = \lambda_1 N_1$, $A_2 = A_1$ $(A_{226}/A_{222} = 1)$.

$^{238}U \rightarrow {}^{234}Th$

$^{230}Th \rightarrow {}^{226}Ra$

$^{226}Ra \rightarrow {}^{222}Rn$

Chemical separation must occur within 5 half lives of N_2 to achieve secular equilibrium.

$\lambda_2 >> \lambda_1$, $\lambda 1$ is insignificant.

If $\lambda_2 >> \lambda 1$, $A_2/A_1 = \lambda_2 /(\lambda_2 - \lambda_1)$.

* Activity of the daughter controlled by activity of parent

– ex. $^{238}U \rightarrow {}^{222}Rn$ in rock:

$^{222}A/^{238}A \sim 1$

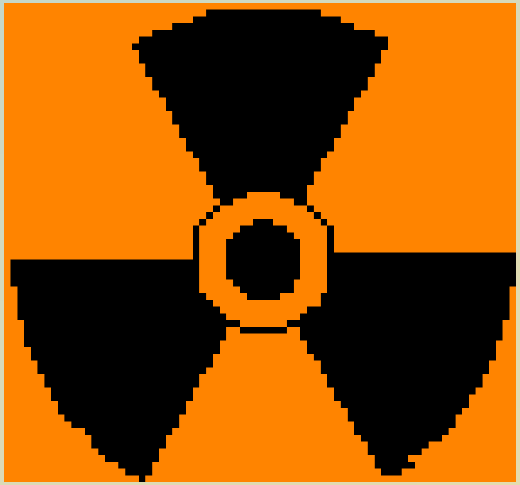
Recoils

– will run along fractures, cracks.

– dislocation - migrates → cracks, fractures.

Radon

- ^{222}Rn - article by A. Nero
  - → controlling variables
  - → health risks
  - → remediation



http://www.radiochemistry.org/periodictable/elements/86.html

http://www.restena.lu/ddnuc/COURS/element/elemrn.htm

Source of Radon: ^{238}U

- ^{238}U is present in crustal rocks at 1-10 ppm.
- goes through series of alpha, beta decays until ^{226}Ra.
- ^{226}Ra –$t_{1/2}$ = 1600 years → ^{222}Rn.
- ^{222}Rn --$t_{1/2}$ = 3.9 days.

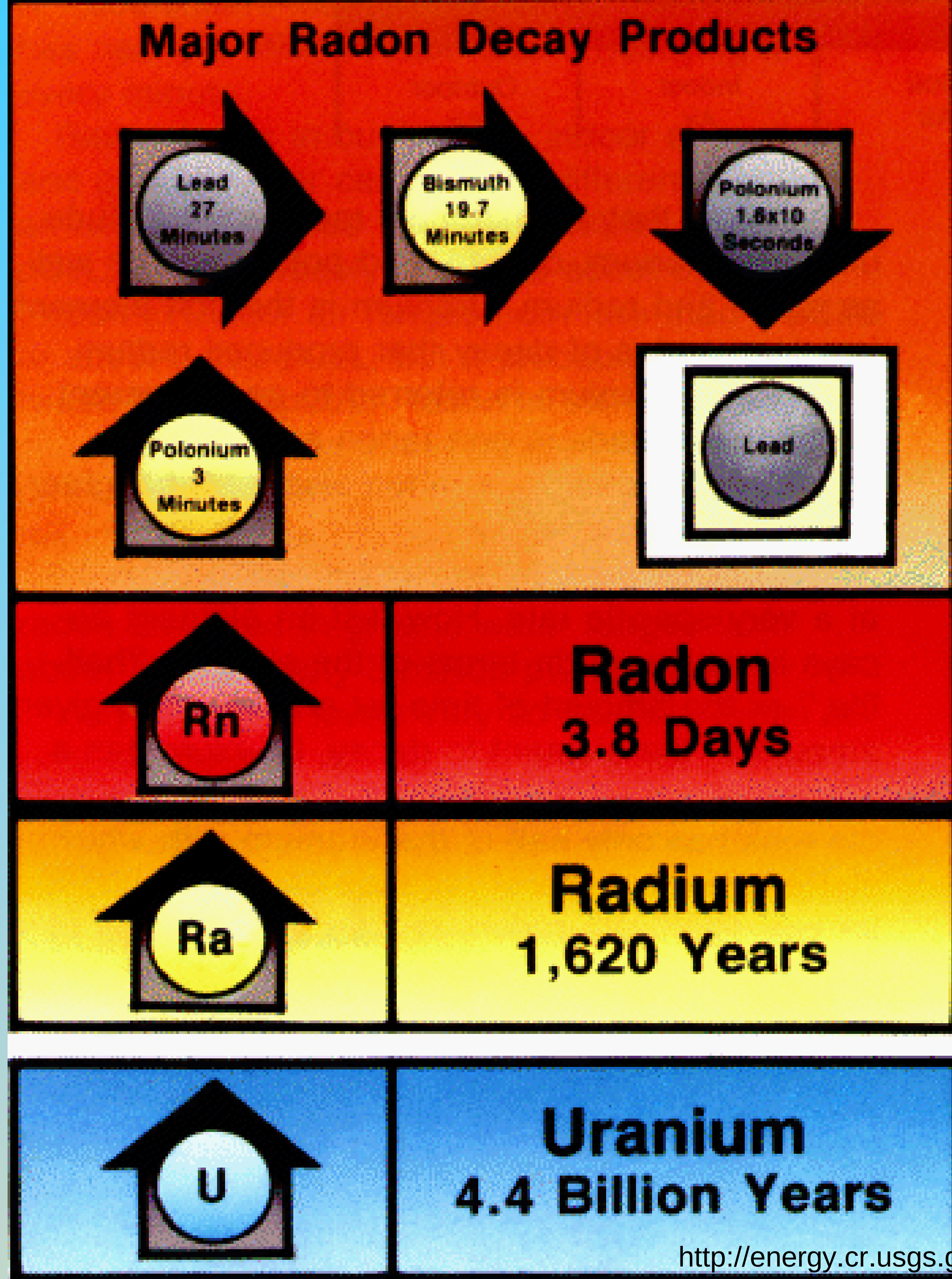
Activities: $^{238}A = ^{226}A = ^{222}A$

A = decays per second (dps) per gram = bq/g

→ therefore A [dps/g].

Secular Equilibrium

- **Decay of daughter product in controlled by the decay of the parent isotope.**
- Therefore - they will all have about equal A's.
- Therefore, U content controls Rn concentration.



http://energy.cr.usgs.gov/radon/georadon/page3.gif

- In ground water setting, ^{226}Ra is more mobile than ^{238}U.
- Potential hazards of radon as an indoor carcinogen (radioactive hazard)

Where does it come from?

- ^{238}U
- ^{222}Rn carried in ground water (doesn't seem plausible).

- But, if you calculate the amount of U present in soil beneath your house, how much of the radon produced gets in the pore spaces of the soil?

*Air is drawn in from the soil beneath your house (30% pore space)

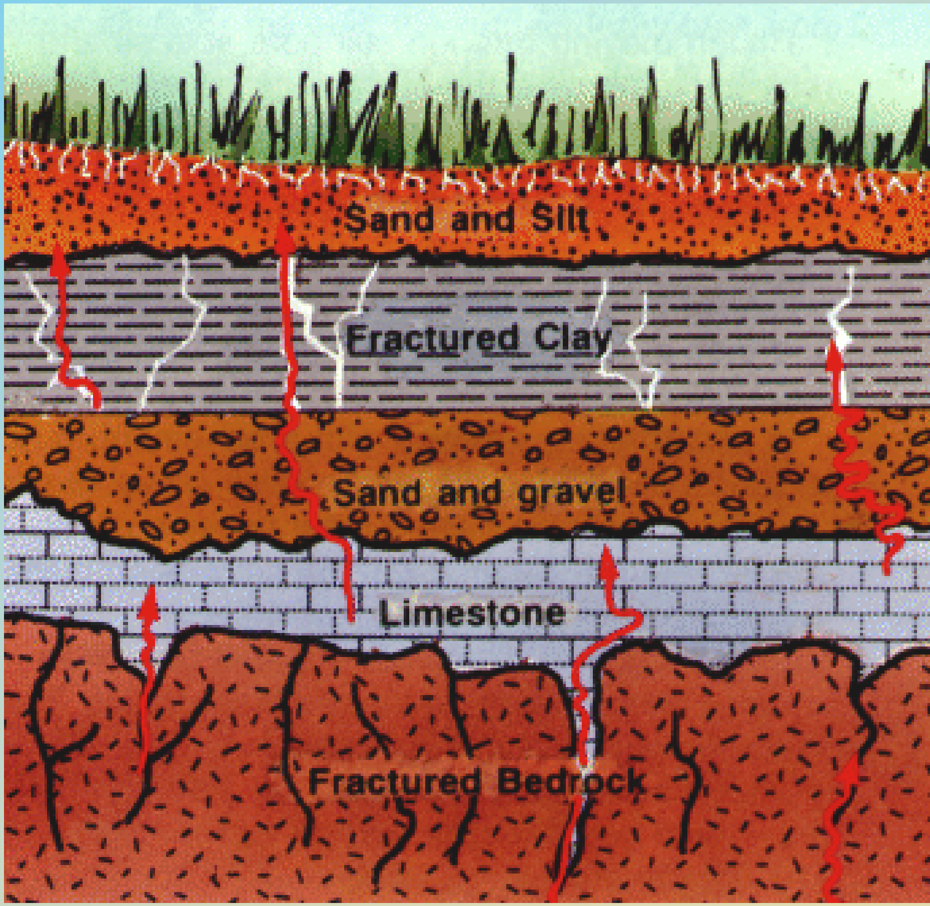
→Therefore this is where it comes from.

Radon in soil:

1. Mean grain size (lower grain size, higher [Rn]).
2. [U] in soil.
3. Thickness of soil
4. Permeability (sandy soil has high permeability, low [U];
   - clay soil has low air flow, high [U]).

How and where is the ^{238}U molecule situated?

- It doesn't have a site in most common crystal lattices (sedimentary deposits).
- Your house is built on quartz, feldspars, micas, clays, carbonates,
- **Therefore, the ^{238}U is often present along the grain boundaries!!**



Some radon atoms remain trapped in the soil and decay to form lead: other atoms escape quickly into the air.

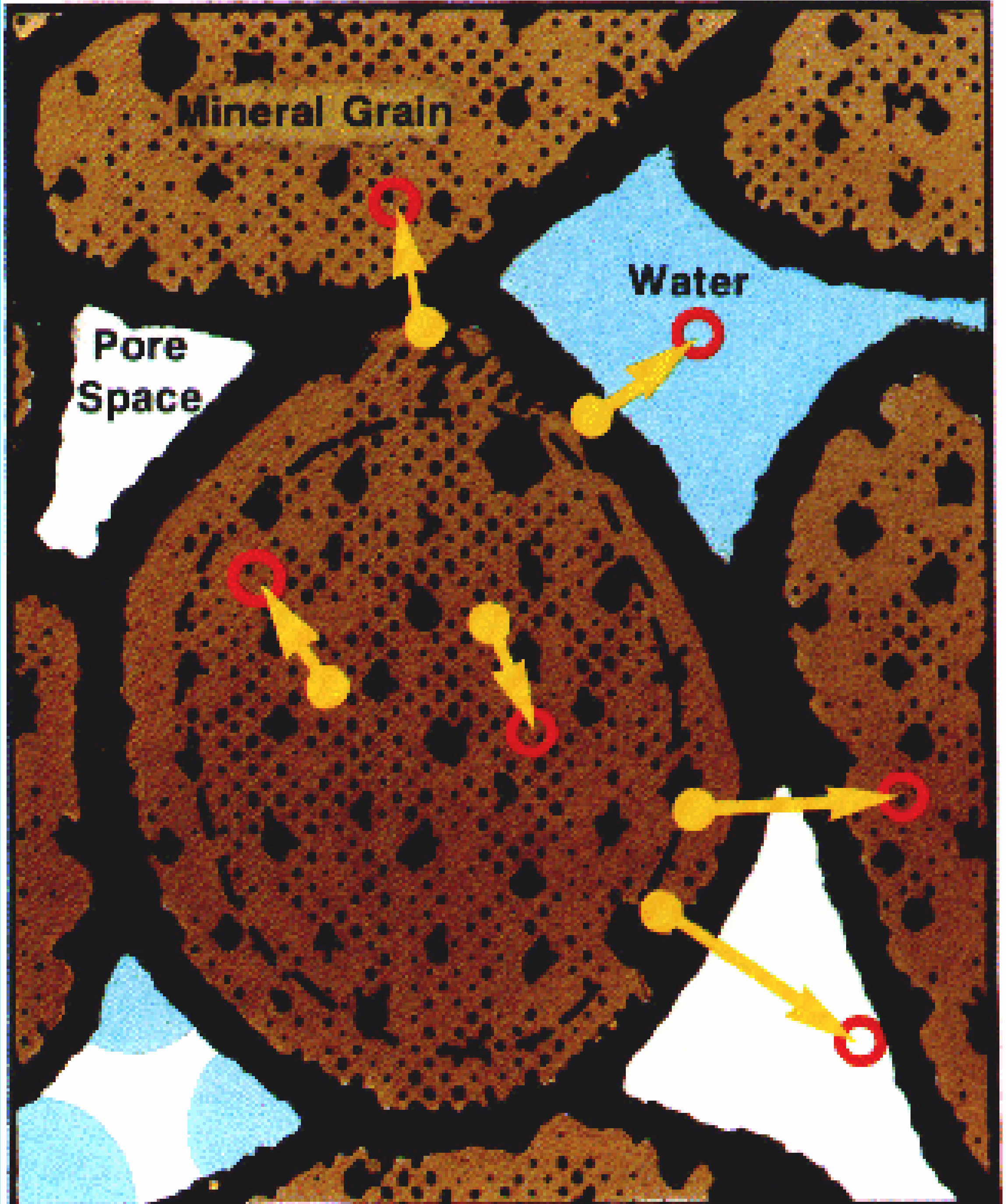
http://energy.cr.usgs.gov/radon/georadon/3.html

- ^{234}U, Th - with each decay, nucleus moves a small finite distance due to conservation of momentum.

    - Therefore, there is displacement.

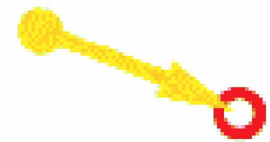
  - Therefore, is 1 ppm U (typical for crustal rocks) --->10,000 Bq/m^3 (1 Bq = 1 dps)
  - If some escapes, still get 10,000 Bq/m^3.
  - Rn can escape from carbonate rocks (porous).

http://energy.cr.usgs.gov/radon/georadon/3.html



Area within a mineral grain from which radon can potentially escape into pore space.

Radium atom before it decays to radon



Newly formed radon atom

Most of the radon produced within a mineral grain remains embedded in the grain, only 10 to 50 percent escapes to enter the pore space. If water is present in the pore space, the radon atom can more easily remain in the pore space; if the pore space is dry, the radon atom may shoot across the pore and embed in another grain where it cannot move.

Controlling Variables on Radon in soil

1. [^{238}U] in soil.
2. Mean grain size
   - **sand vs clay, U is more likely to be located near grain boundary in clay because there is a higher surface area/volume ratio.**
   - **Rn loss is a function of grain size.**

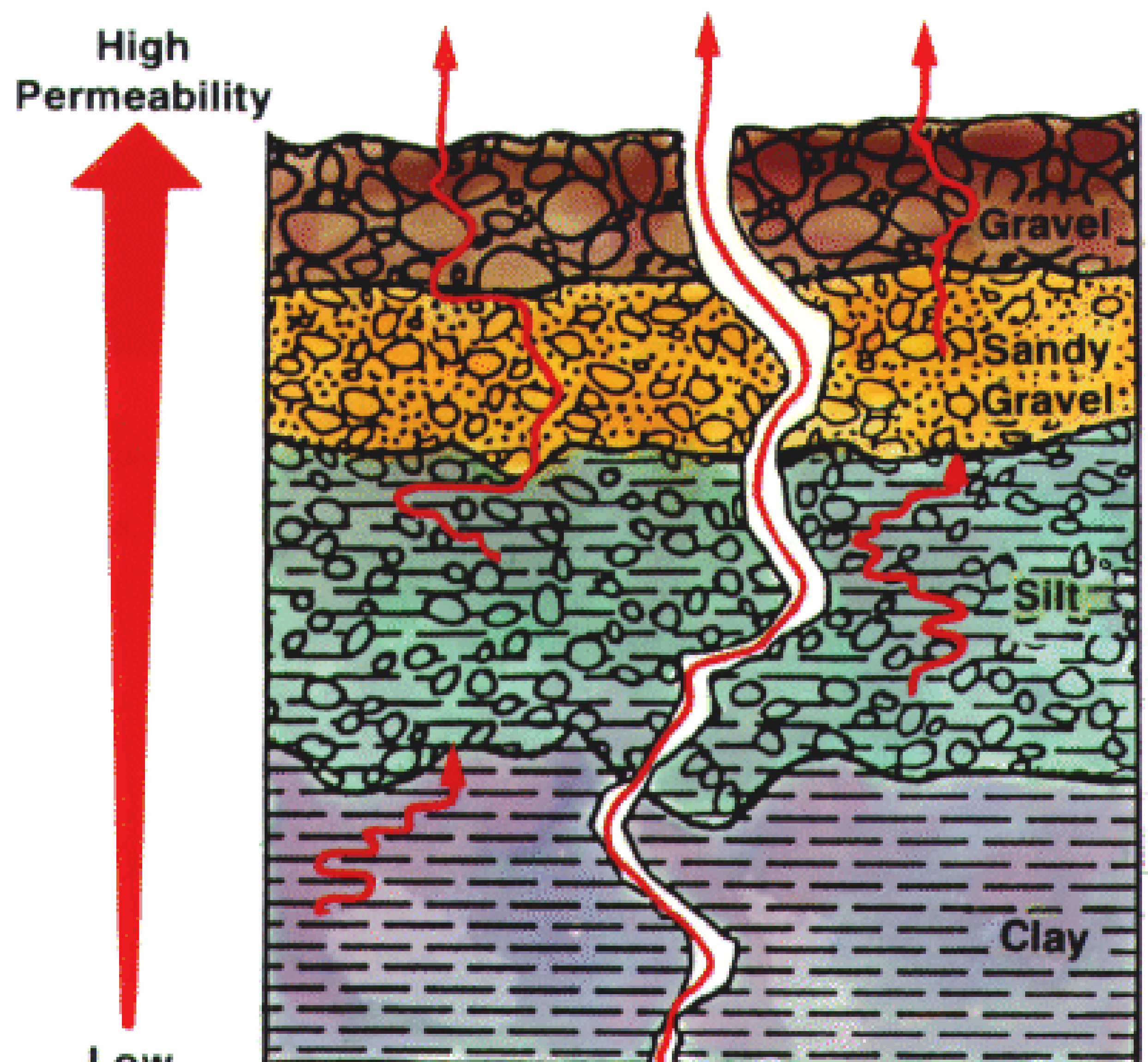
Controlling Variables on Radon in soil

3. Permeability

   – flow → flows are slower in clay than in sand.

   – permeability decreases as grain size decreases.

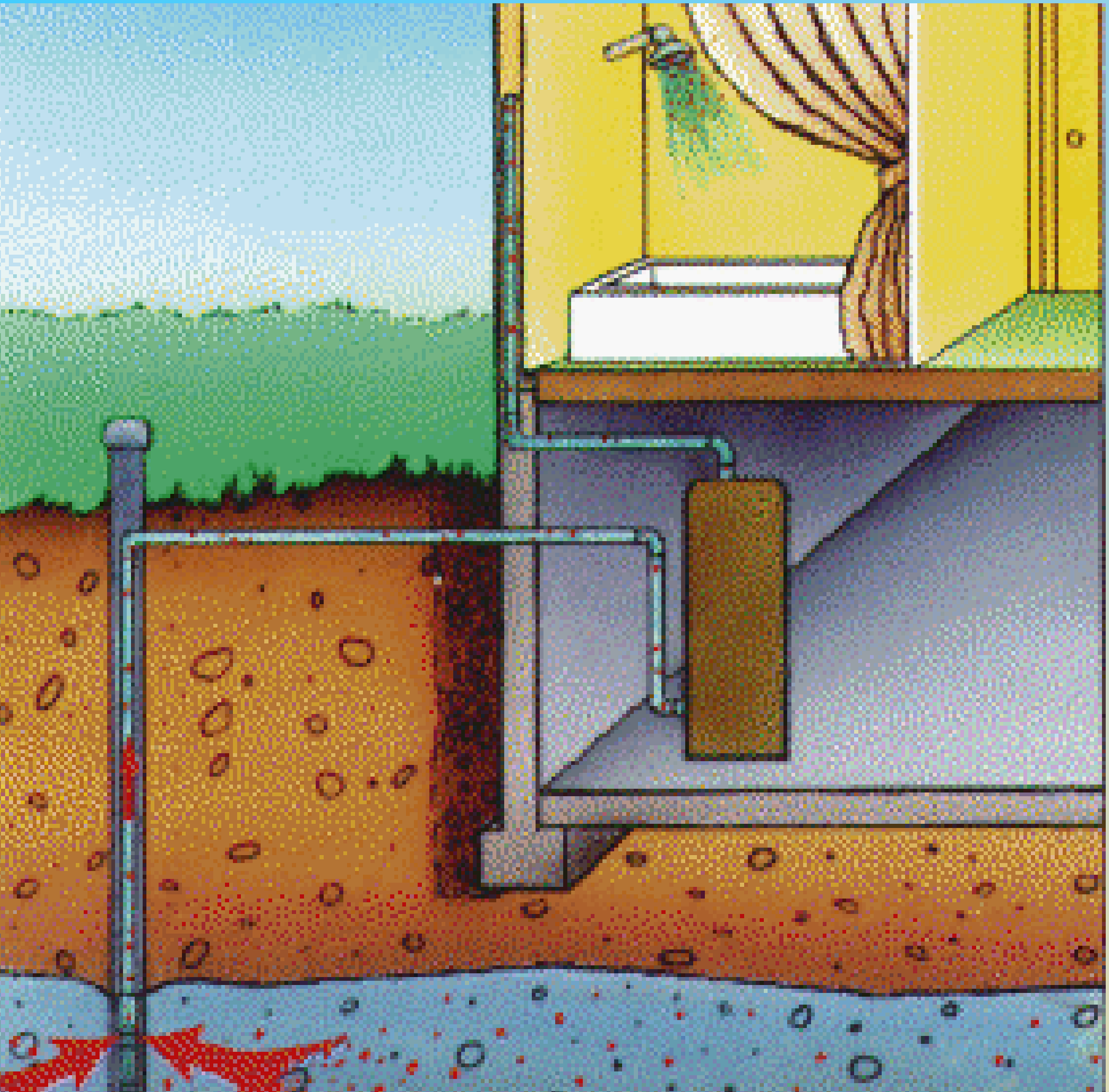
   – most remediation schemes attempt to reduce permeability.

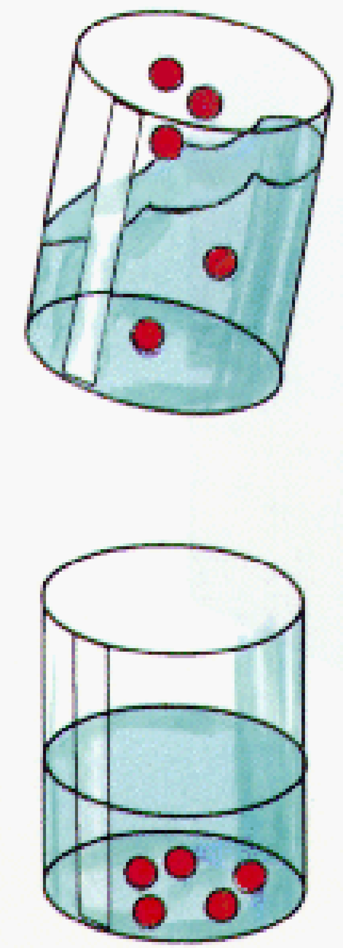


Radon can move through cracks in rocks and through pore spaces in soils.

http://energy.cr.usgs.gov/radon/georadon/3.html

In areas where the main water supply is from private wells and small public water works, radon in ground water can add radon to the indoor air.





Radon escapes from water when it is agitated.

http://energy.cr.usgs.gov/radon/georadon/3.html

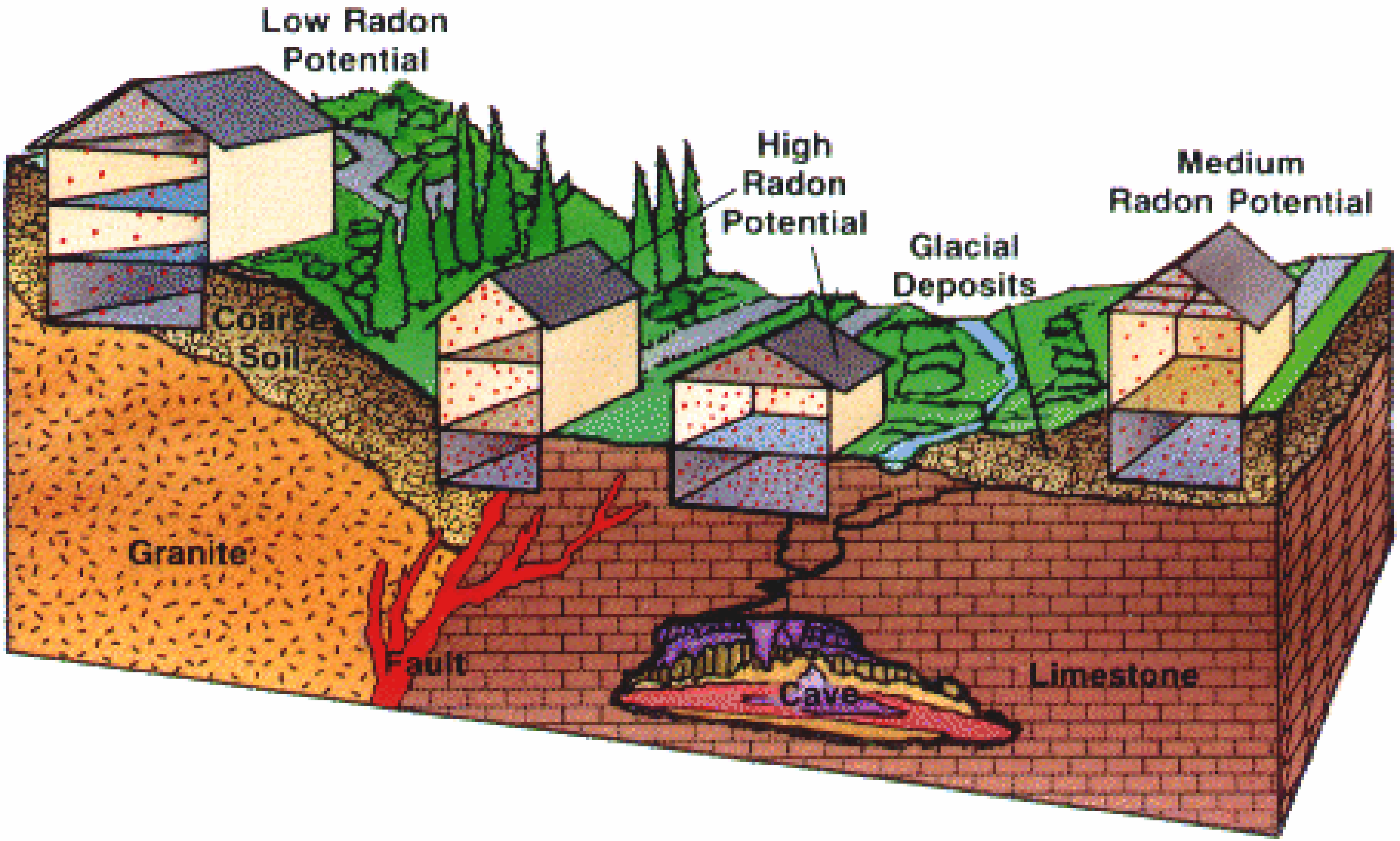
Controlling Variables on Radon in soil

4. [Rn] in ground water is not a problem at 0-20 Bq/L, unless used for a domestic source (Rn produced from U decay enters ground water).

Risk factors?

- only 1-10% Rn present has to leak out to cause problems.
- [^{222}Rn] in soil directly determines the [^{222}Rn] in the house (is a way to remediate this).

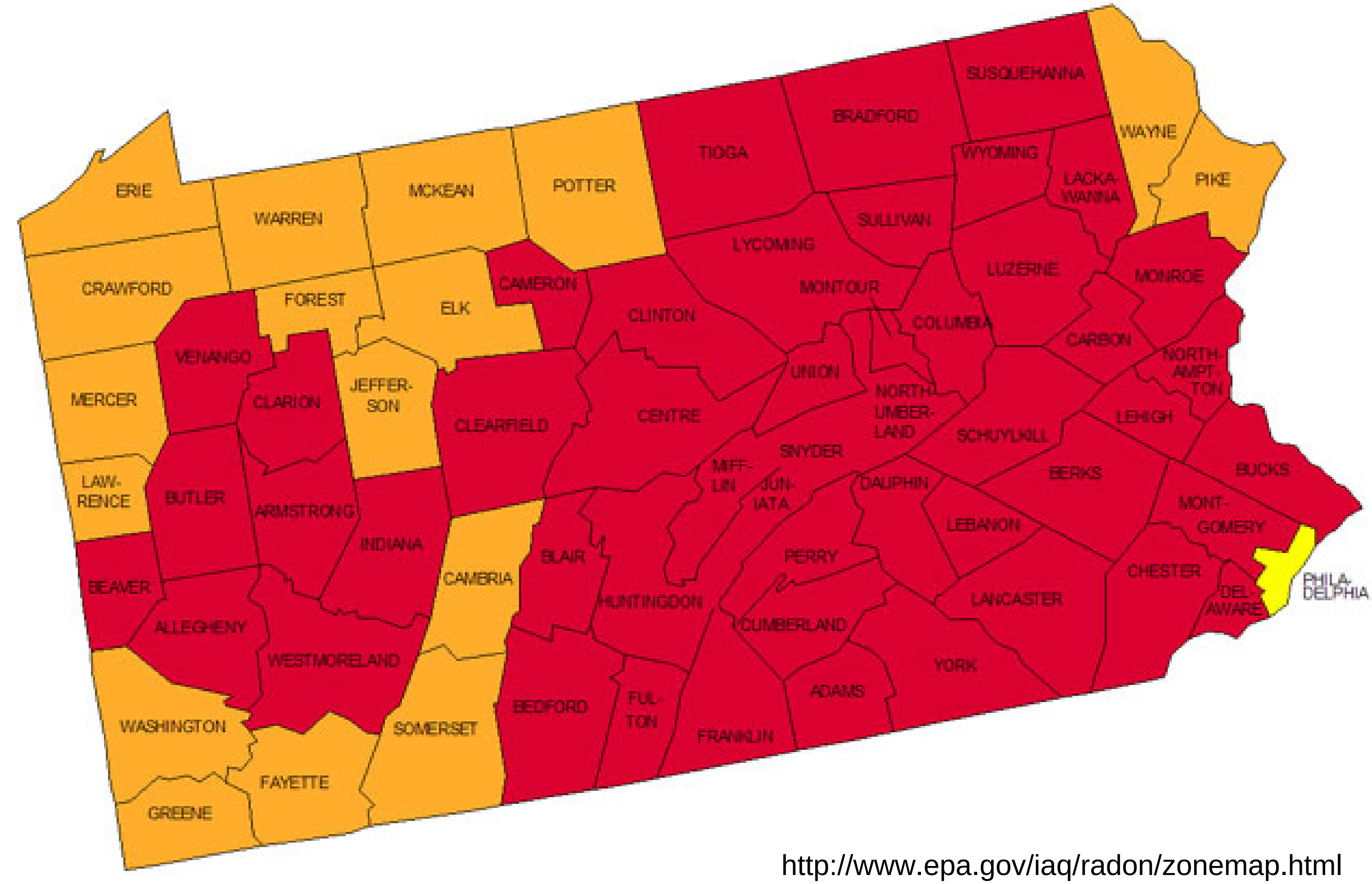
Radon Potential



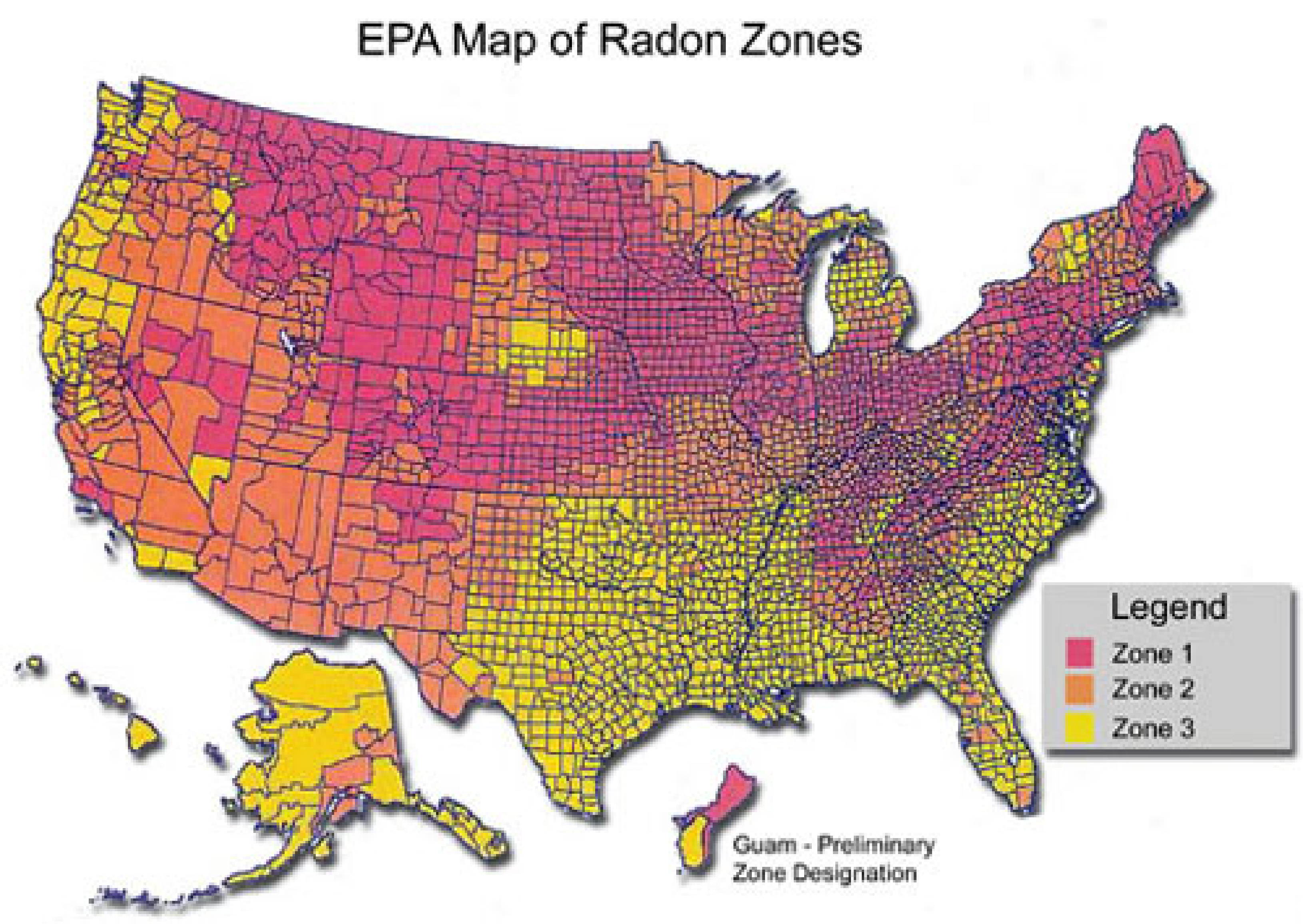
http://energy.cr.usgs.gov/radon/georadon/page4.gif

EPA Map of Radon Zones - Pennsylvania

	Zone 1	**Highest Potential (greater than 4 pCi/L)**
	Zone 2	**Moderate Potential (from 2 to 4 pCi/L)**
	Zone 3	**Low Potential (less than 2 pCi/L)**



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



Zone 1 **Highest Potential (greater than 4 pCi/L)**

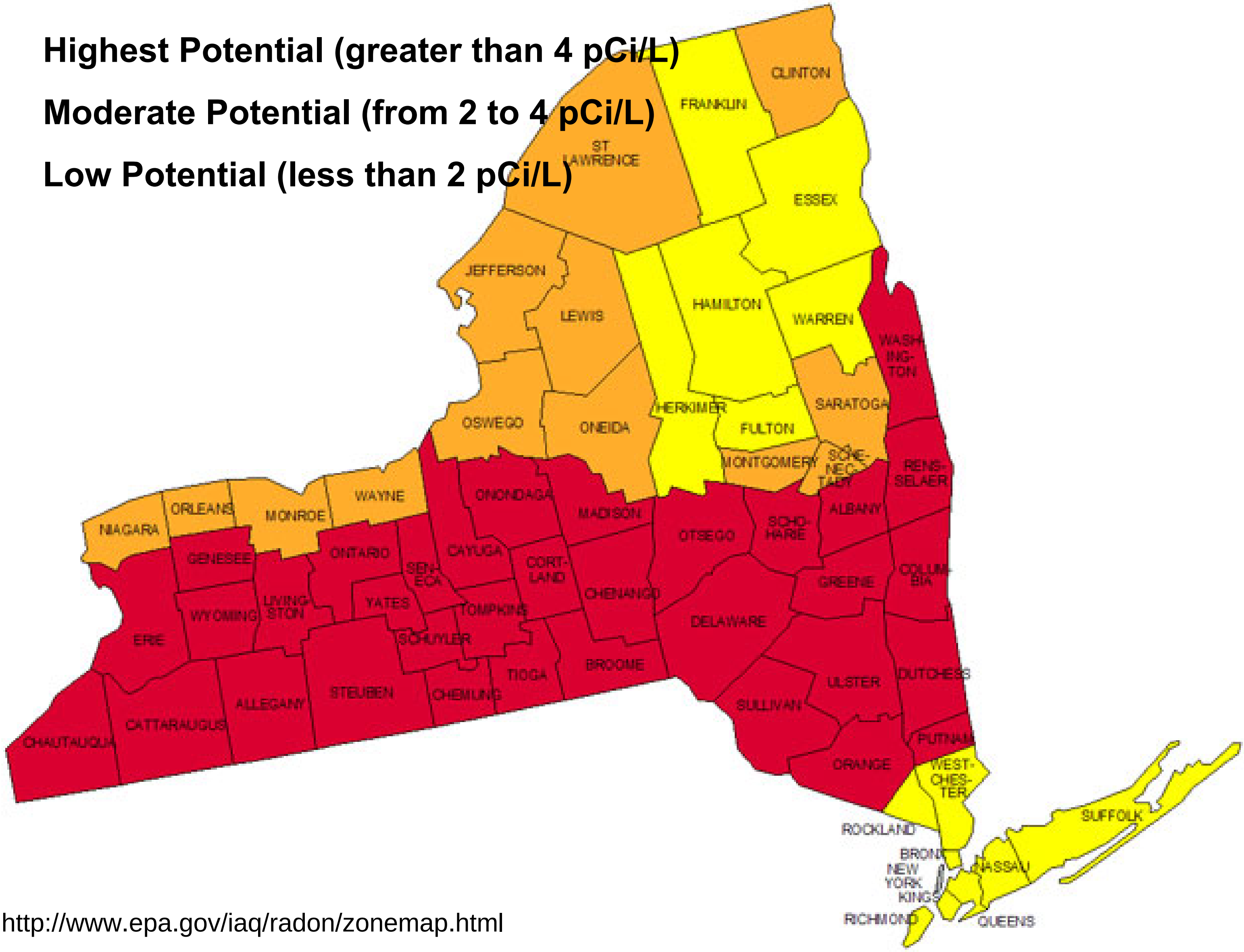
Zone 2 **Moderate Potential (from 2 to 4 pCi/L)**

Zone 3 **Low Potential (less than 2 pCi/L)**

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

EPA Map of Radon Zones- New York State

Zone 1	Highest Potential (greater than 4 pCi/L)
Zone 2	Moderate Potential (from 2 to 4 pCi/L)
Zone 3	Low Potential (less than 2 pCi/L)



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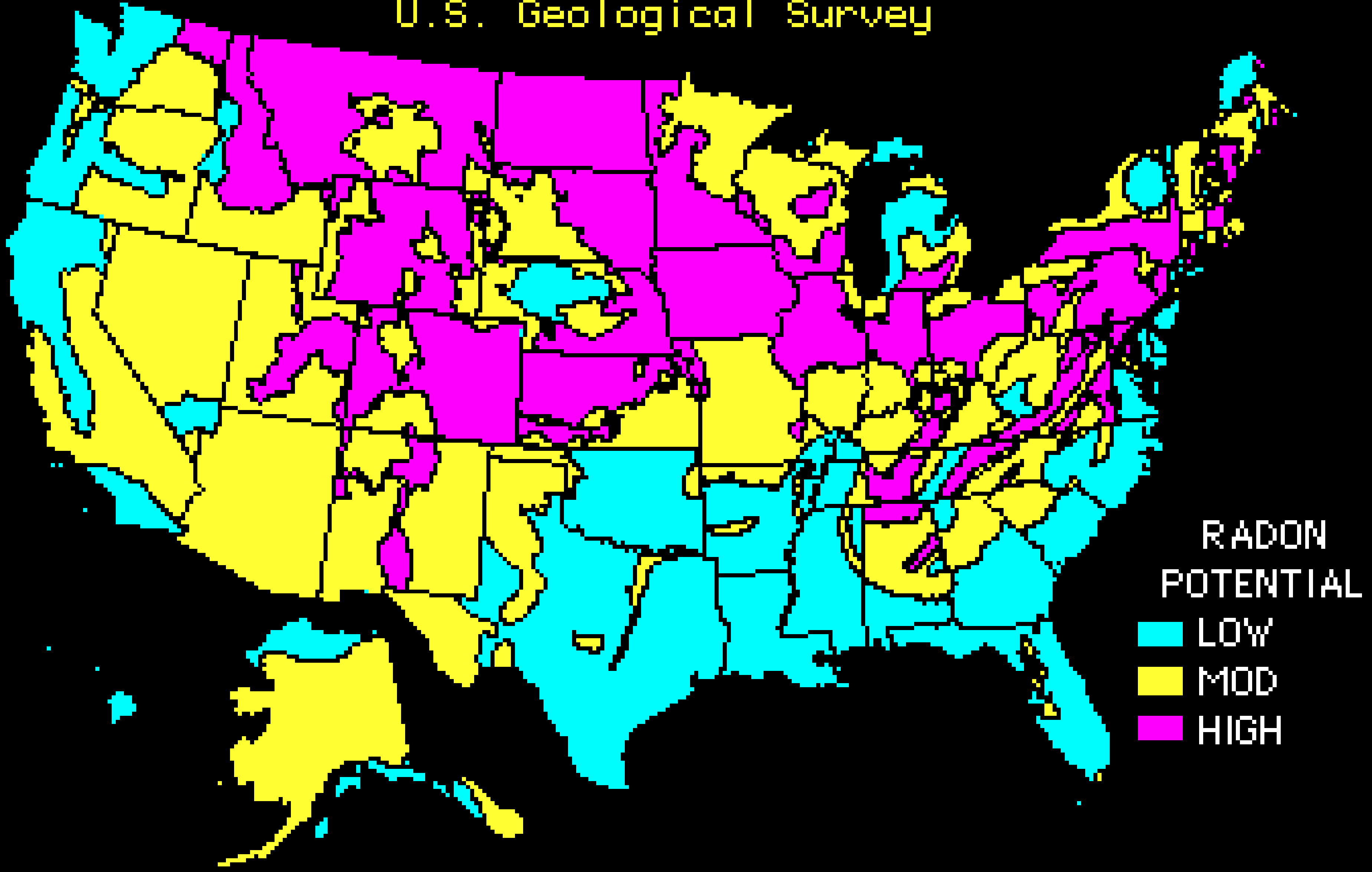
GEOLOGIC RADON POTENTIAL OF THE UNITED STATES

U.S. Geological Survey



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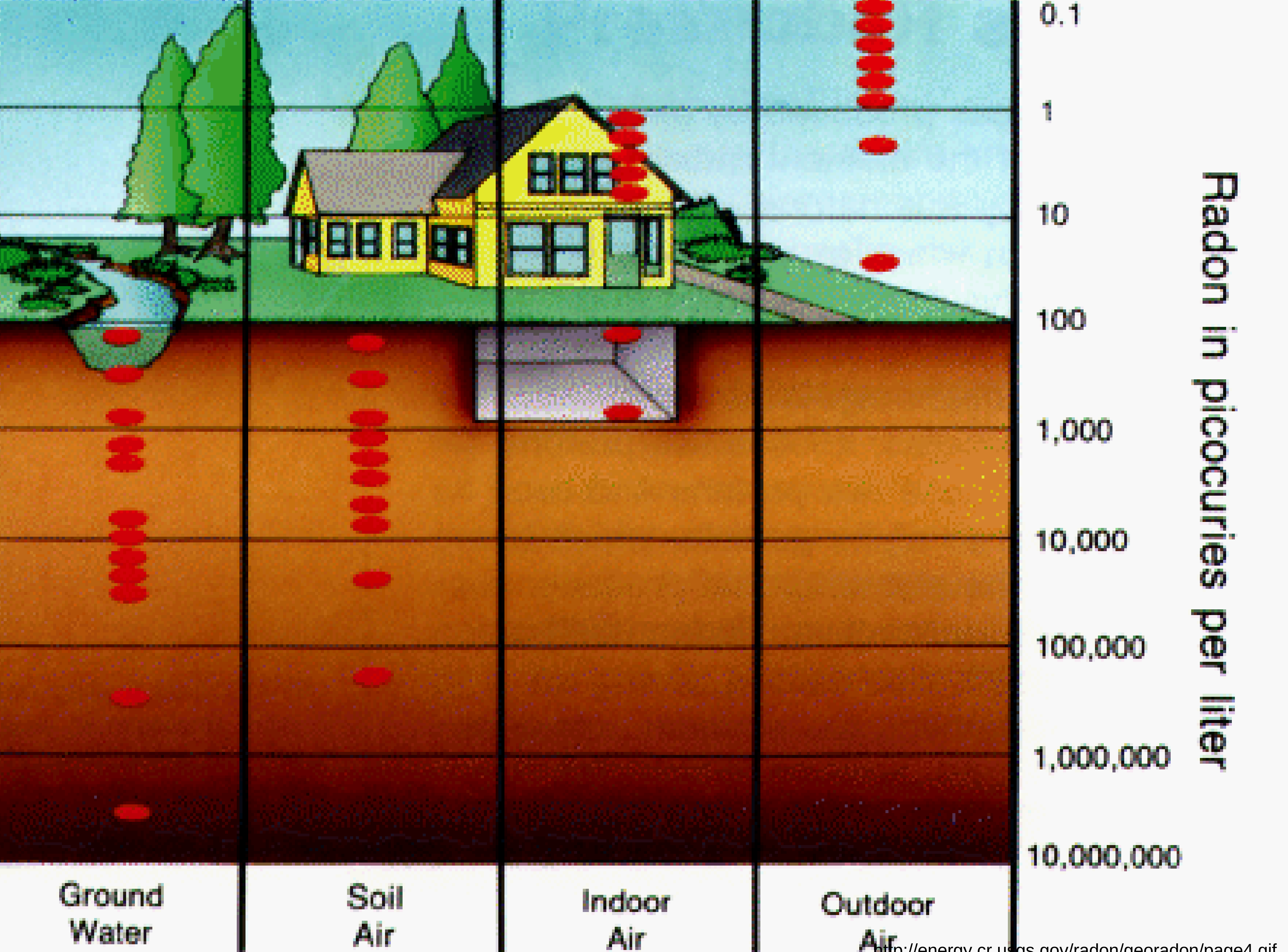


http://energy.cr.usgs.gov/radon/georadon/page4.gif

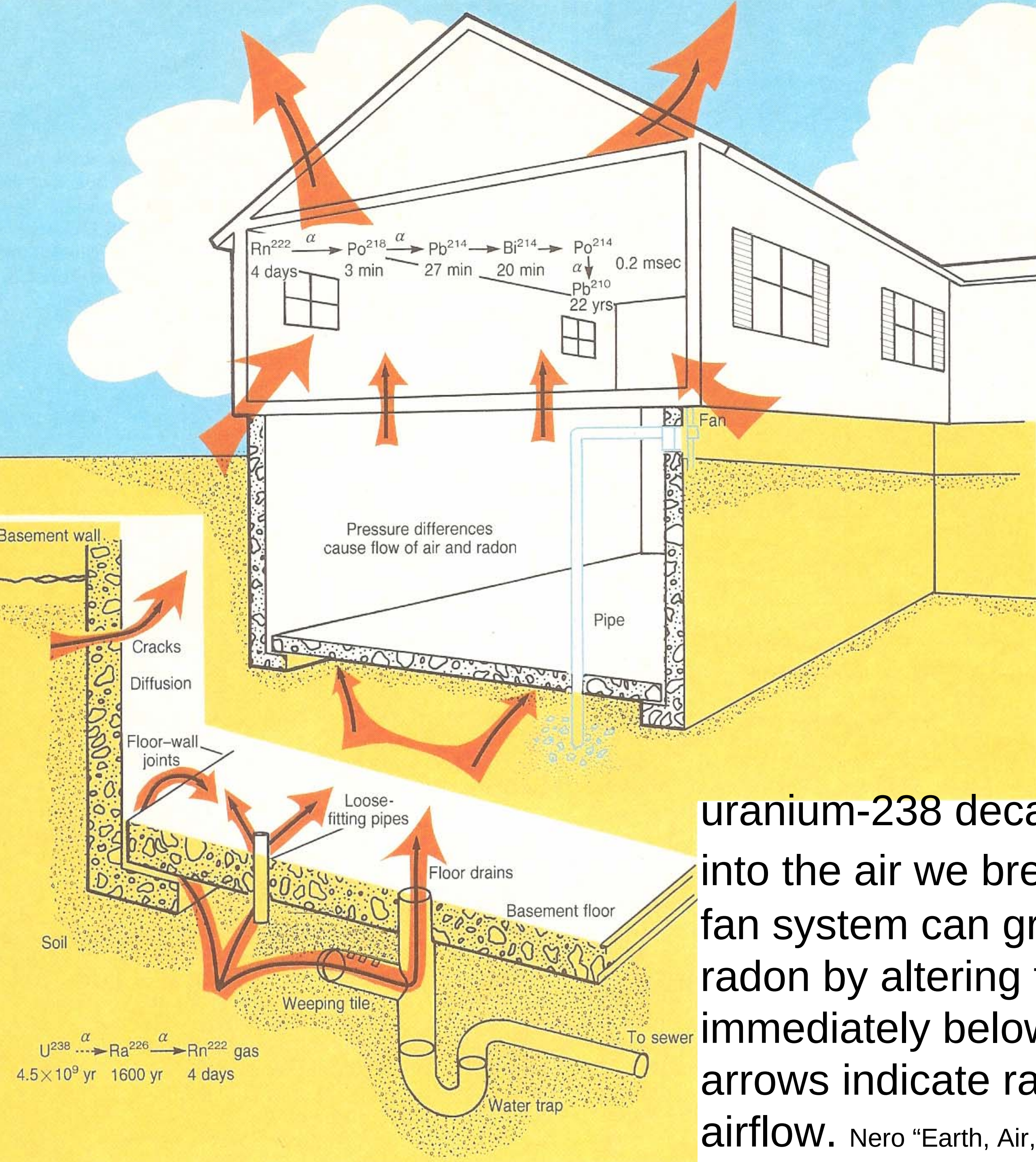
- Average [^{222}Rn]house is about 50 Bq/m^3 of air
- Average [^{222}Rn]soil is about 100 - 10,000 Bq/m^3 of air
- Average [^{222}Rn]outside air is about 1-2 Bq/m^3

An increase of 50 Bq/m^3, increases the risk by 5 times.

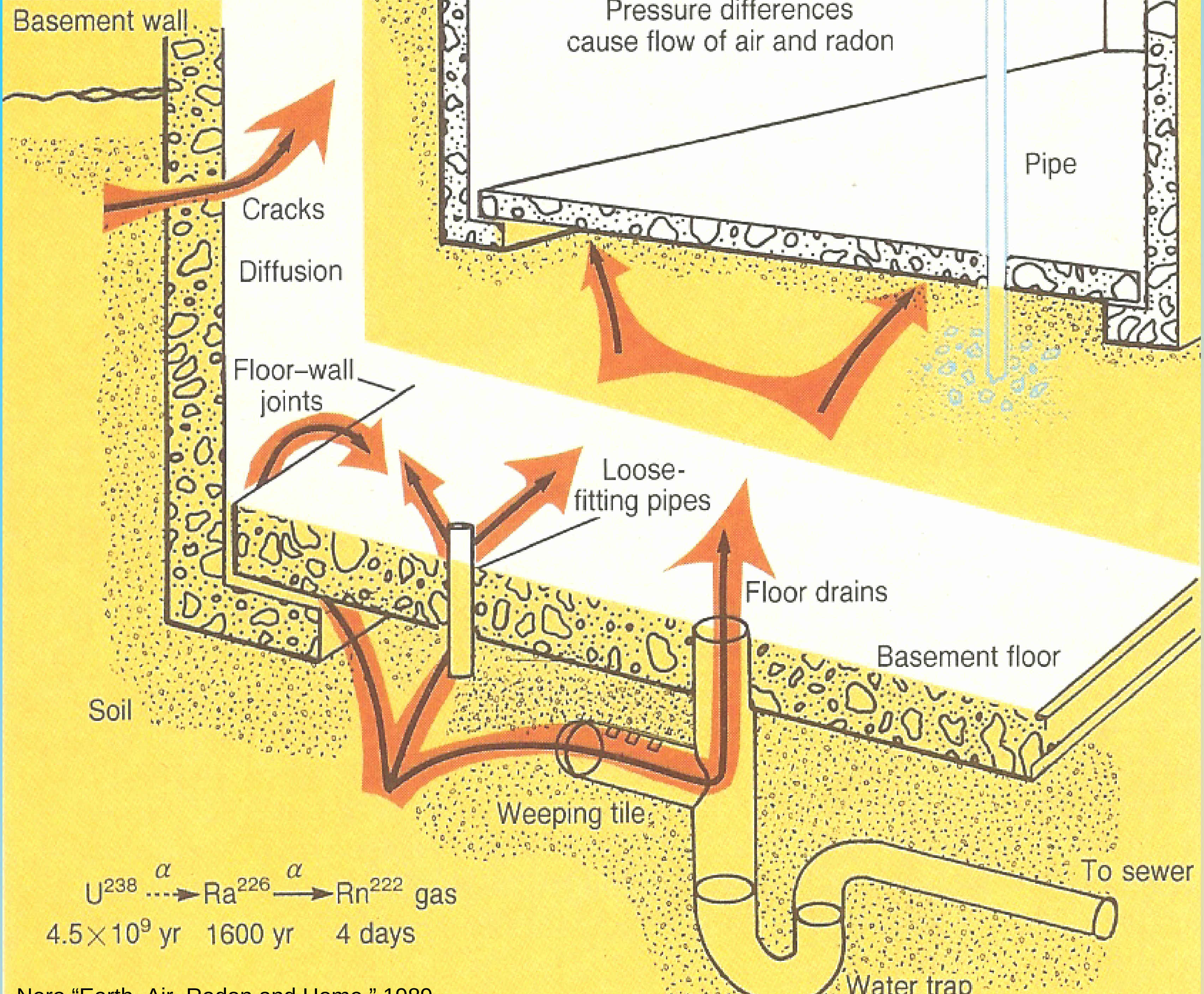
People in natural exposure (underground U mines)

- **about 15 - 20 times average background limit.**

→a high incidence of lung cancer, etc.



Flow of radon into homes. The primary mechanism is the drawing of soil gas through the ground and understructure by small pressure differences generated by winds and by indoor-outdoor temperature differences. These pressures, which also account for the general bentilation of most homes, effectively transport part of the uranium-238 decay chain from the ground into the air we breathe. A simple pipe-and-fan system can greatly reduce the influx of radon by altering the pressure in the ground immediately below the house. Black arrows indicate radon flow; orange arrows, airflow. Nero "Earth, Air, Radon and Home," 1989



Nero “Earth, Air, Radon and Home,” 1989

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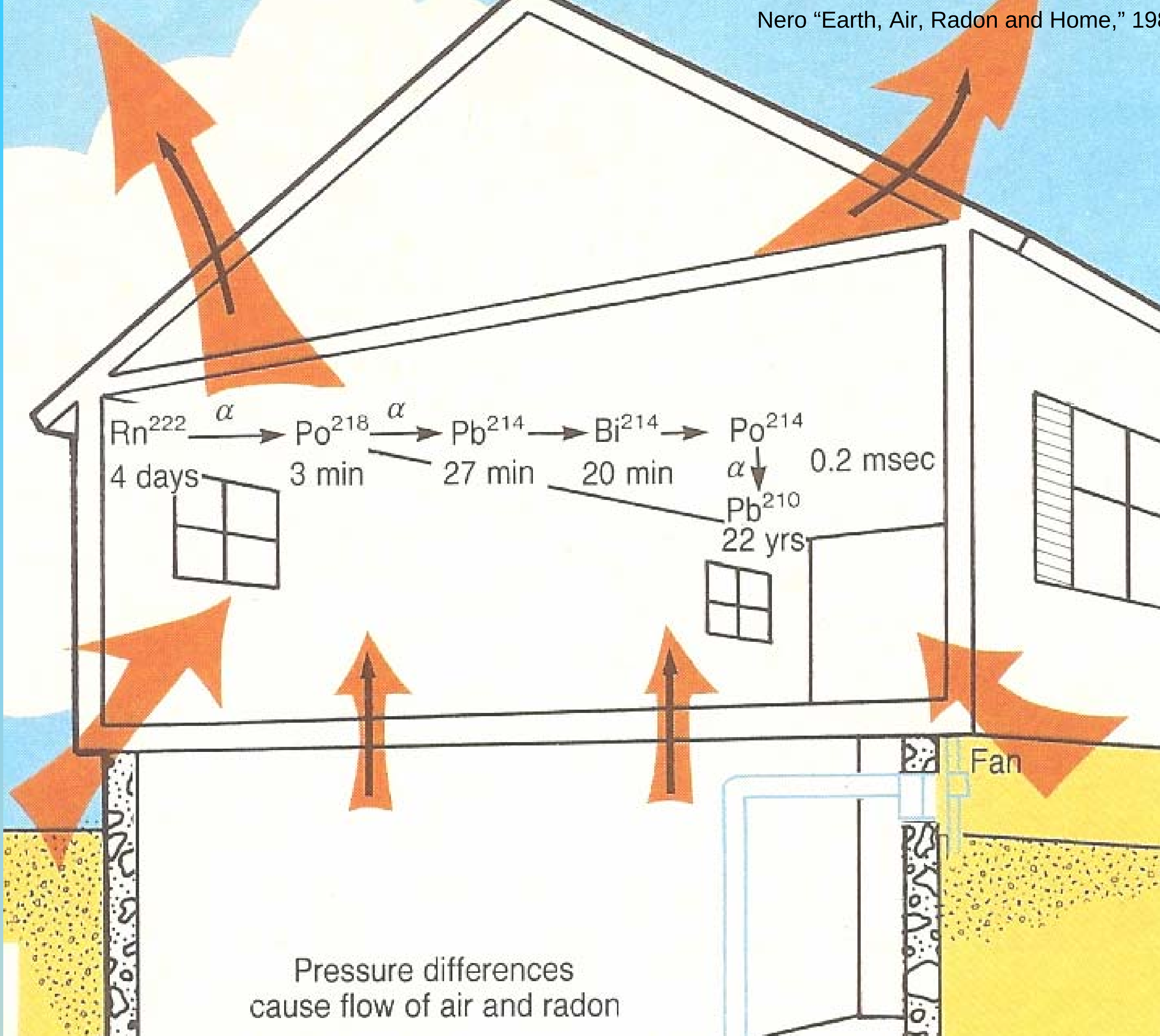

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$^{222}Rn - \alpha \rightarrow {}^{218}Po - \alpha \rightarrow {}^{214}Pb \rightarrow {}^{214}Bi \rightarrow {}^{214}Po \rightarrow$
$^{210}Pb \rightarrow {}^{210}Po \rightarrow {}^{206}Pb$.

^{222}Rn, $t_{1/2}$ ~ 3.9 days.

^{218}Po, $t_{1/2}$ = 3 minutes (carry much energy, don't penetrate -- Gamma particles don't penetrate skin, but can hurt lung linings).

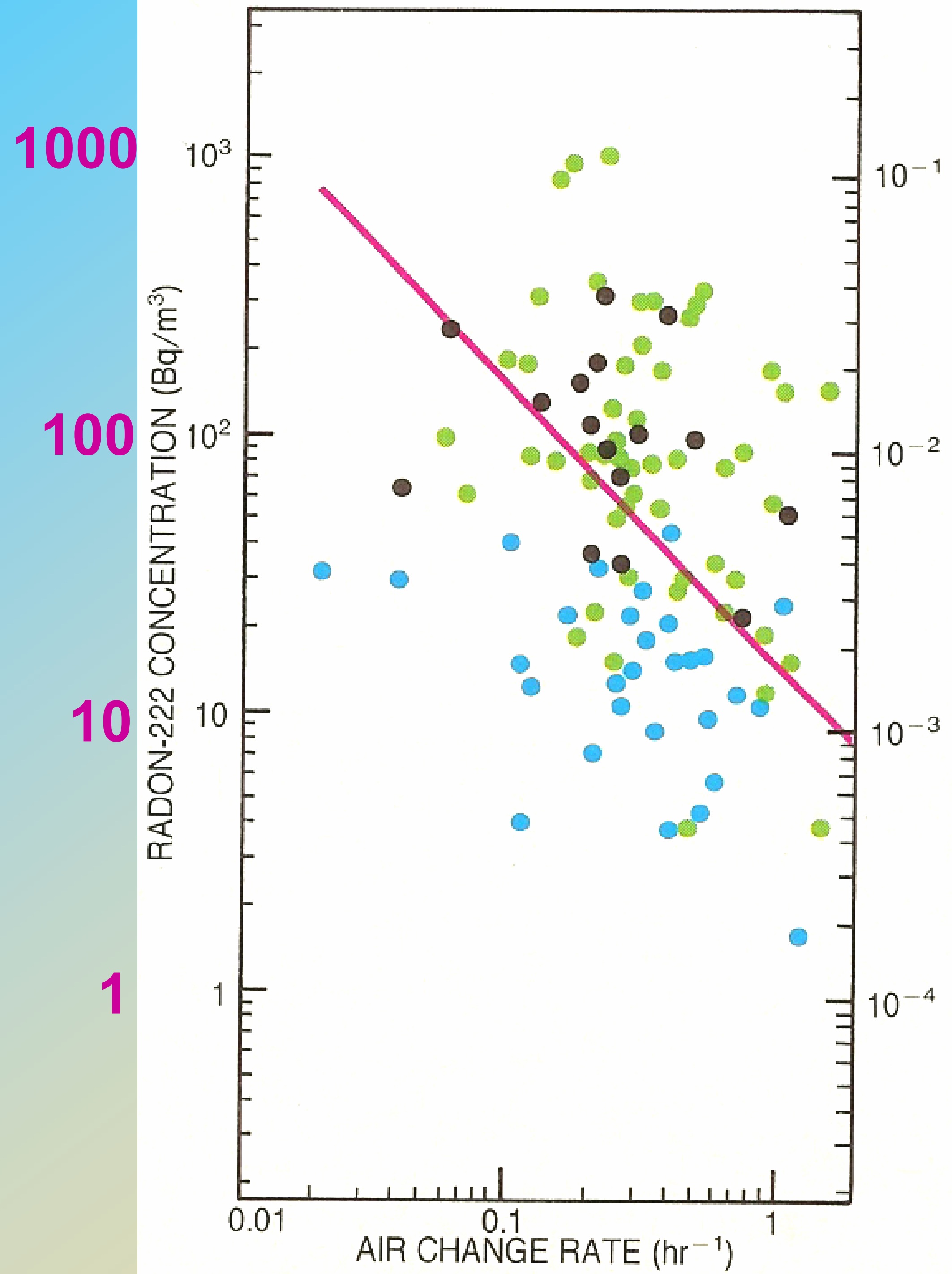
^{214}Bi, $t_{1/2}$ = 27 minutes.

^{210}Pb, $t_{1/2}$ = 22 years.

^{210}Po, $t_{1/2}$ = 138 days.

→**The alpha decays are the bad actors.**

Radon concentration vs ventilation rate in 100 homes. The two parameters show little correlation in this log-log plot. If they were inversely related, as they are in houses that have the same radon entry rate, the data would fall along a straight line like that shown. Black circles represent energy efficient homes; blue, homes in San Francisco; green, homes in Maryland 1pCi/L=37Bq/m3

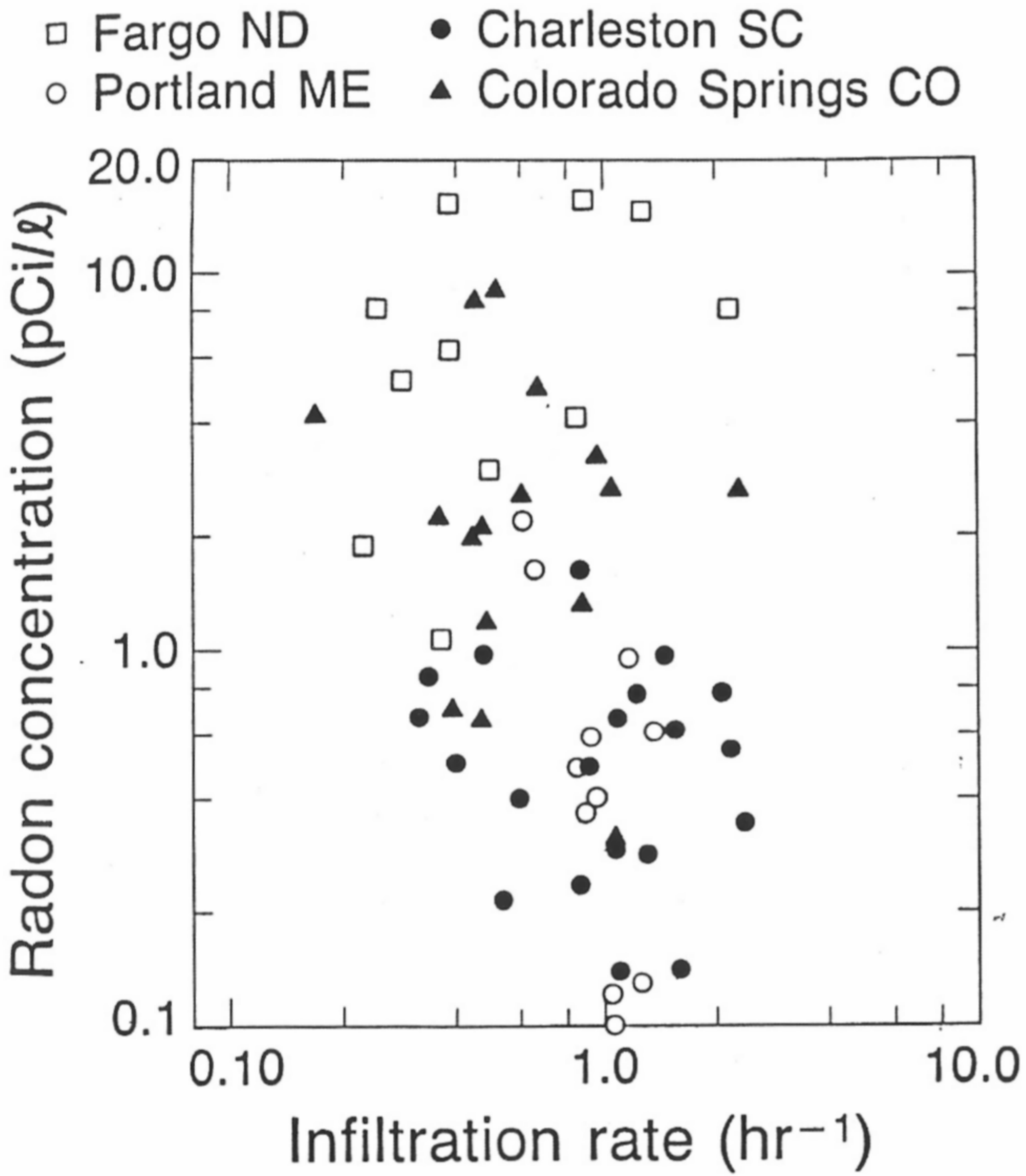


Nero “Earth, Air, Radon and Home,” 1989

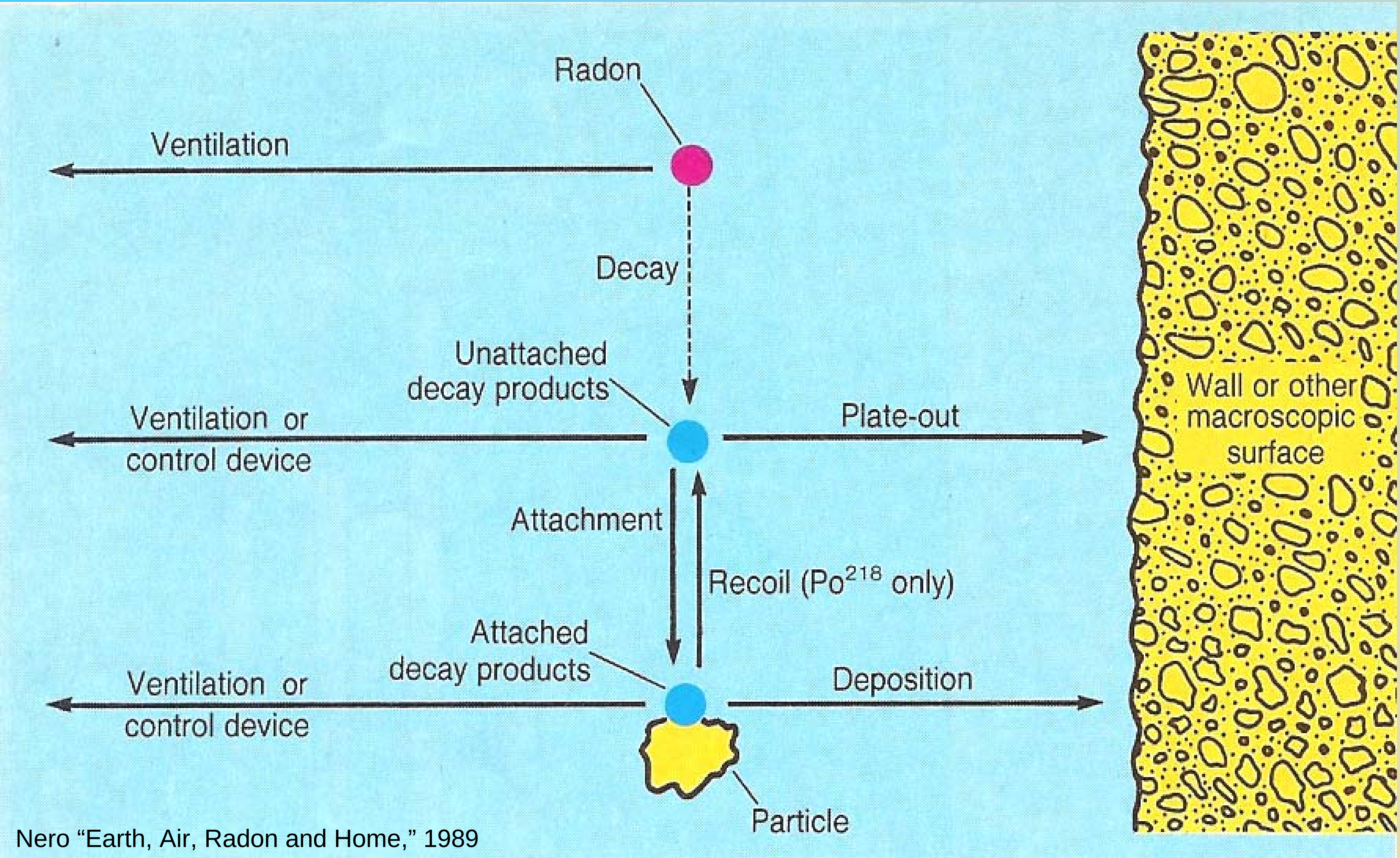
Figure 3.3

Scatter plot of time-averaged radon concentration and air infiltration rates measured in 58 houses in four U.S. cities

1pCi/L=37Bq/m^3



Removal processes. Radioactive decay products leave the indoor air through deposition on walls (wither as "unattached" particles of attached to preexisting particles) and thorugh ventilation or control devices that use processes such as filtration or electrostatic precipitation.



Nero "Earth, Air, Radon and Home," 1989

- **There is steady-state [Rn] in your lungs because [^{222}Rn] is about constant in your house** because the decay constant (l) of Rn is about 0.01 hr^{-1}.
- Flux of house air → house exchange/hour.
- [^{222}Rn]house is about constant, whether it comes from soil, or leaky windows/doors.
- **A percentage of Rn in your house will decay in your lungs.**

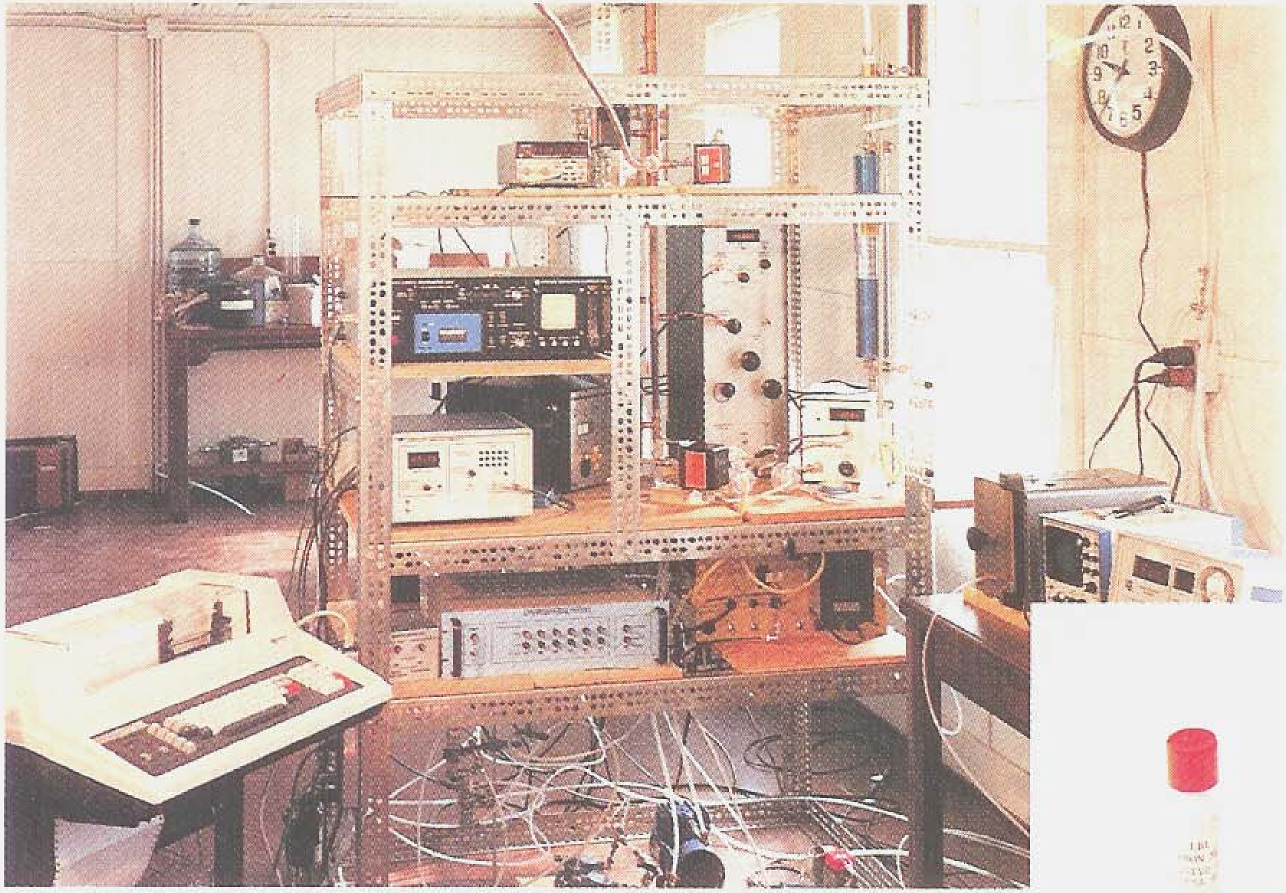
- Initially, you want to reduce ^{222}A.
- If there are a lot of particles in your house (ie. smoke, dust), a certain percentage of these particles enter your lungs with attached Pb and Po.
- If there are fewer particles in your house, more Pb, Po remain unattached and have a better chance of getting into your lungs (?)
- **Seems to reduce [^{222}A]**

→equivalent energy/decay concentration.

1.0 is complete

.3 - .5 = e.e.d.c.

→**Pb, Po damage epithelial lining of lungs.**



< Instrumentation for characterizing particle and decay-product size distributions. This information is needed as a basis for understanding doses and hence risks.

Samplers for radon and other indoor pollutants. Such passive devices offer a simple means for assessing public exposures. >

Nero “Earth, Air, Radon and Home,” 1989

Methods:

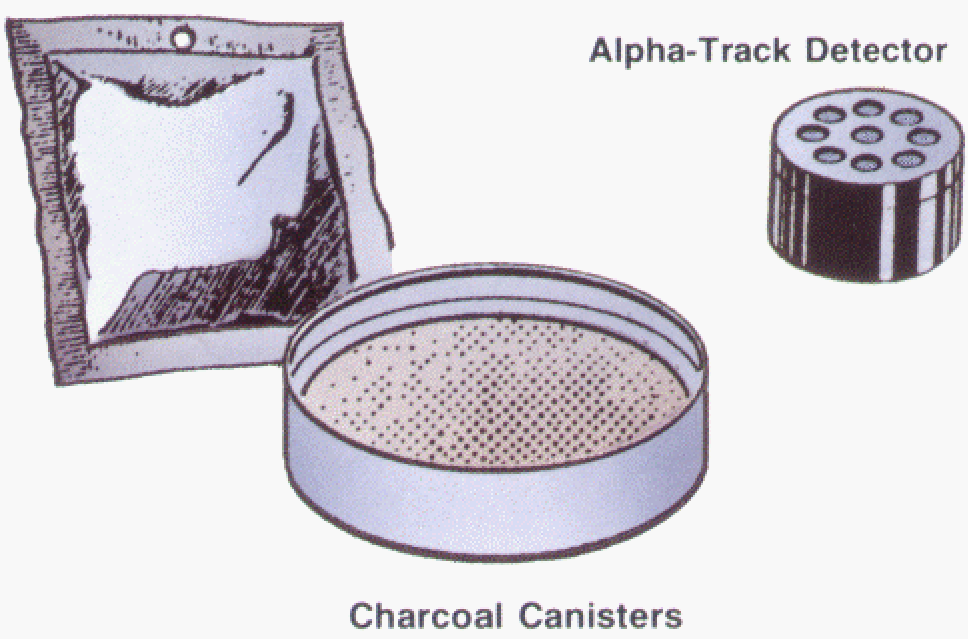
1. **Charcoal canister**:

–Activated charcoal is a large molecule trap.

–Coconut charcoal works best, but gas is adsorbed.

–The larger the molecule, the easier it is adsorbed (ie. Rn, H_2O adsorb at T = ambient;)

–After trap Rn, send off to lab which count it to find out the concentration of Rn.



•In soils : 1000 - 10000 Bq/m^3

•Houses: about 50 Bq/m^3; about 1.4 pCi/Liter air.

(curie = 3.7 x 10^{10}dps; pCi = .037 dps).

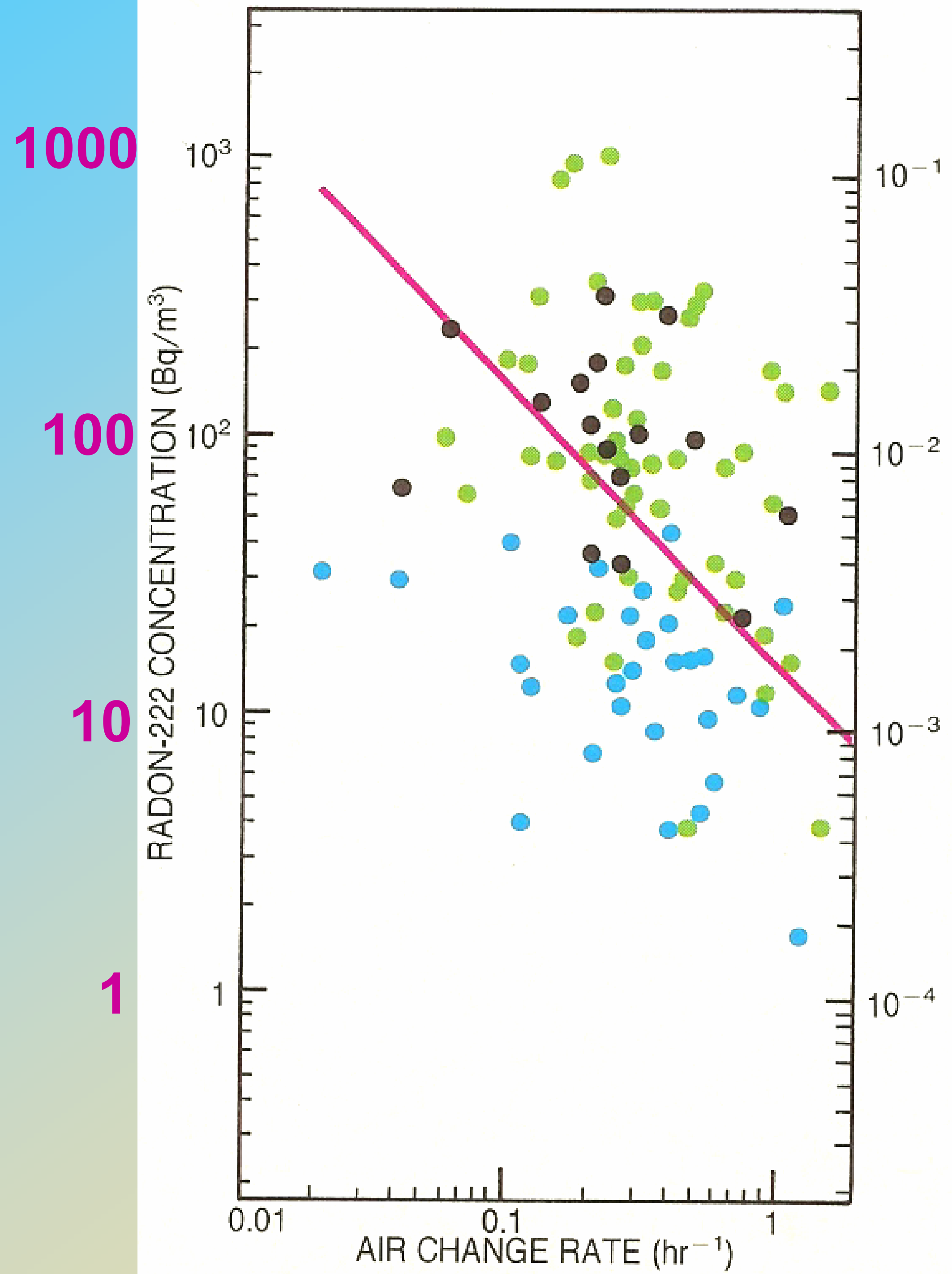
Problems:

- The number measured is quite accurate, but what does it mean?
- **Where to put it?** Recommend in basement in which the concentration of Rn is 3 - 5 times higher than the rest of the house due to less mixing.
- Basements are very humid and charcoal loves to grab water vapor → therefore, sites to which Rn would adsorb are taken up by H_2O (Resulting in a lower number with higher humidity).
- How representative is the air flow?
- Potential for large seasonal variation related to relative humidity, air exchange, etc.

^{222}Rn, when decays by alpha decay, it leaves a track:

- Polycarbide film records the track caused by Rn decay.
- Count number of tracks in cm^2, the number of tracks is proportional to A.
- May have pump to slow steady air flow across film, may give better results.
- May include heater to keep water (gas) away or it can't record the track on film, but heating can cause the tracks to anneal.

Radon concentration vs ventilation rate in 100 homes. The two parameters show little correlation in this log-log plot. If they were inversely related, as they are in houses that have the same radon entry rate, the data would fall along a straight line like that shown. Black circles represent energy efficient homes; blue, homes in San Francisco; green, homes in Maryland



Nero “Earth, Air, Radon and Home,” 1989

In houses:

- Distribution is about 38 Bq/m^3.
- Geometric s.d.: = 2.8

x 2 = 5.6 → 95% conf. interval

95% c.i. is 38 x 5.6 = 210 at 2 sigma

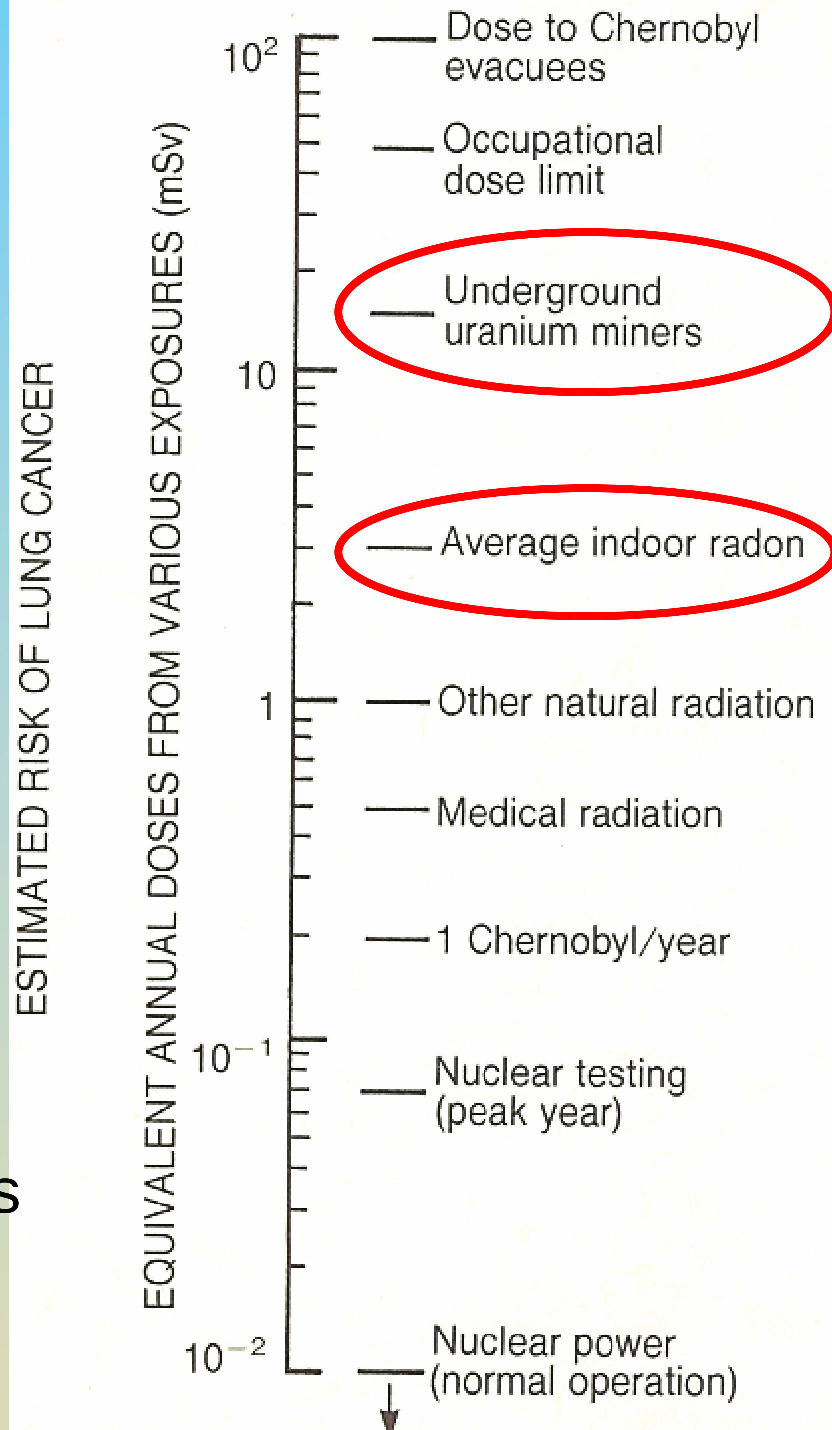
320 Bq/m^3 → 1% of houses at 3 sigma .

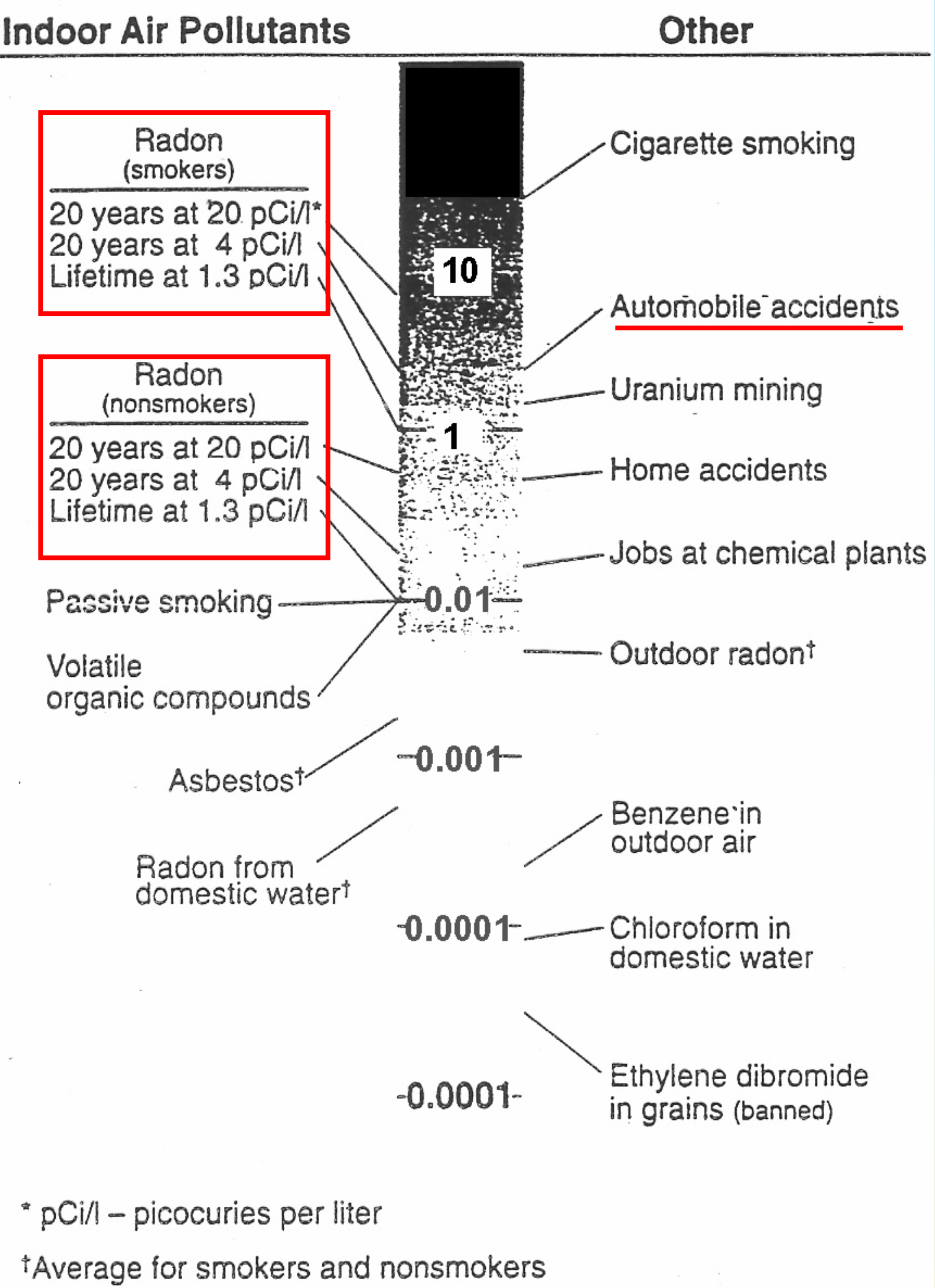
- At what level should you remediate?
- What do you use as a standard?
- Lifetime risk of lung cancer is high with exposure.
- 7% is risk for smoking.

What do the different exposures mean in terms of cancer risk?

- **Average exposure → .5% lung cancer risk**
- **Uranium mining → 5% incidence death from lung cancer.**

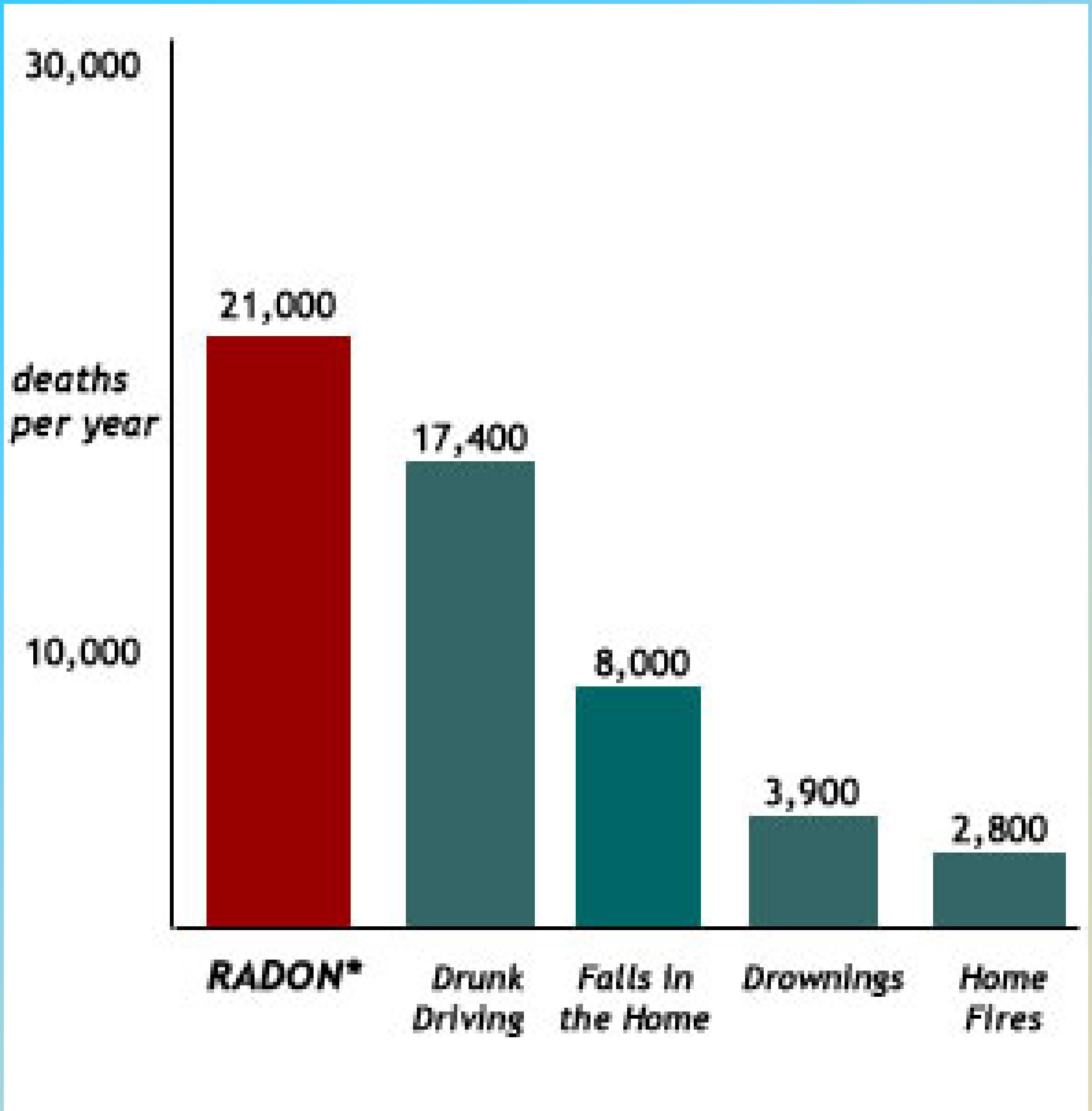
Estimates of lung cancer risk for > lifetime occupancy. Radiation doses from other sources are indicated for comparison. Nero "Earth, Air, Radon and Home," 1989





Estimated Lifetime Risk of Premature Death (Percent)

All risks are average for the whole population except where indicated. Radon estimates presume a ten-fold difference between smoker and nonsmoker risks due to synergism, but the exact ratio is not known. In the unlikely event that these actually is no difference between the two groups, the risk for the general population would be just below home accidents for a lifetime at 1.3 pCi/l, somewhat above home accidents for 20 years at 4 pCi/l, and above the risk from auto accidents for 20 years at 20 pCi/l.



Radon is estimated to cause thousands of lung cancer deaths in the U.S. each year.

* Radon is estimated to cause about 21,000 lung cancer deaths per year, according to EPA's 2003 Assessment of Risks from Radon in Homes (EPA 402-R-03-003). The numbers of deaths from other causes are taken from the Centers for Disease Control and Prevention's 1999-2001 National Center for Injury Prevention and Control Report and 2002 National Safety Council Reports.

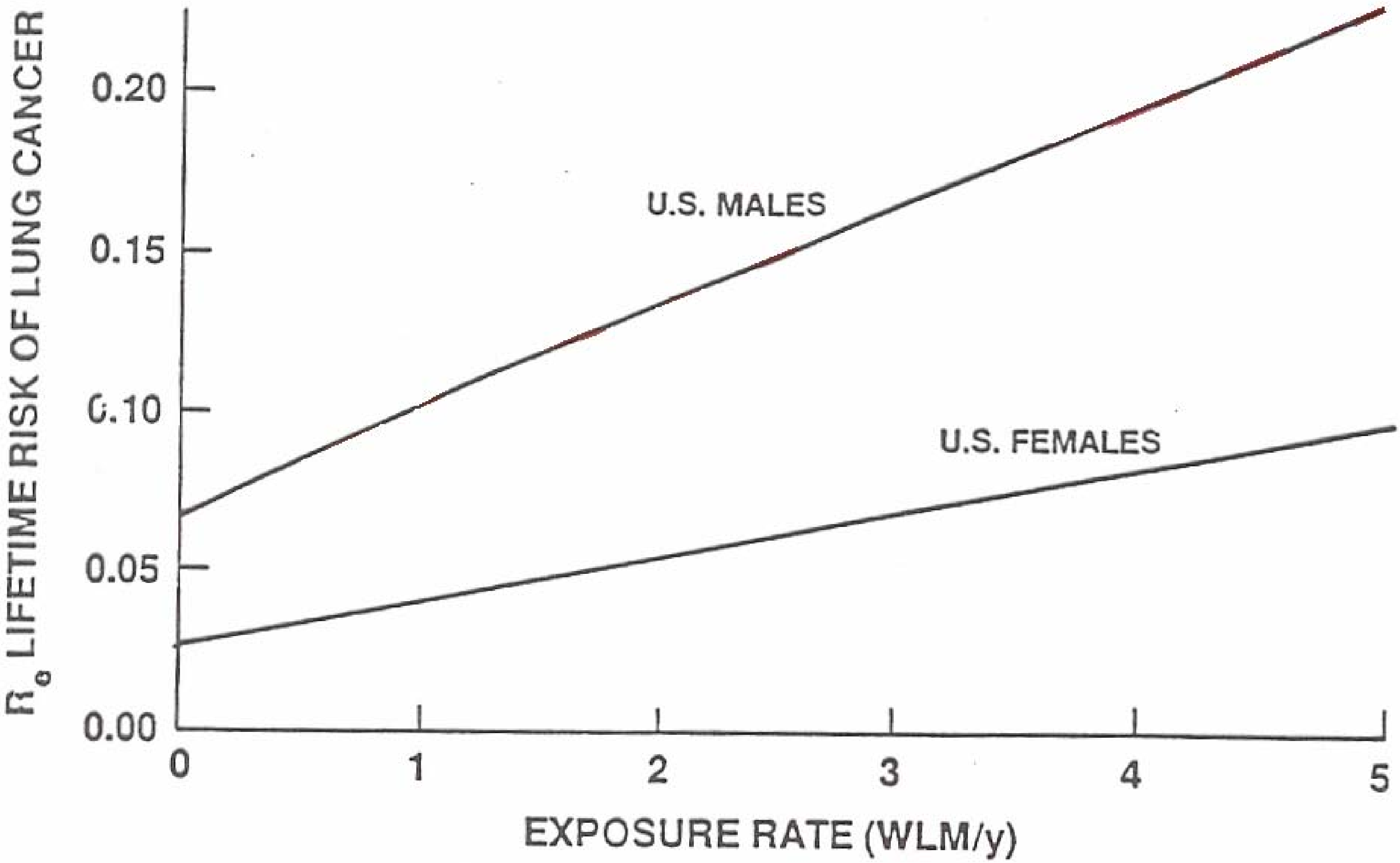


FIGURE 2-3 Lifetime risk of lung-cancer mortality (R_e) for lifetime exposure to radon progeny at constant rates of annual exposure.

Average years of life lost ($L_o - L_e$) due to lifetime exposure to radon progeny at constant rates of annual exposure.

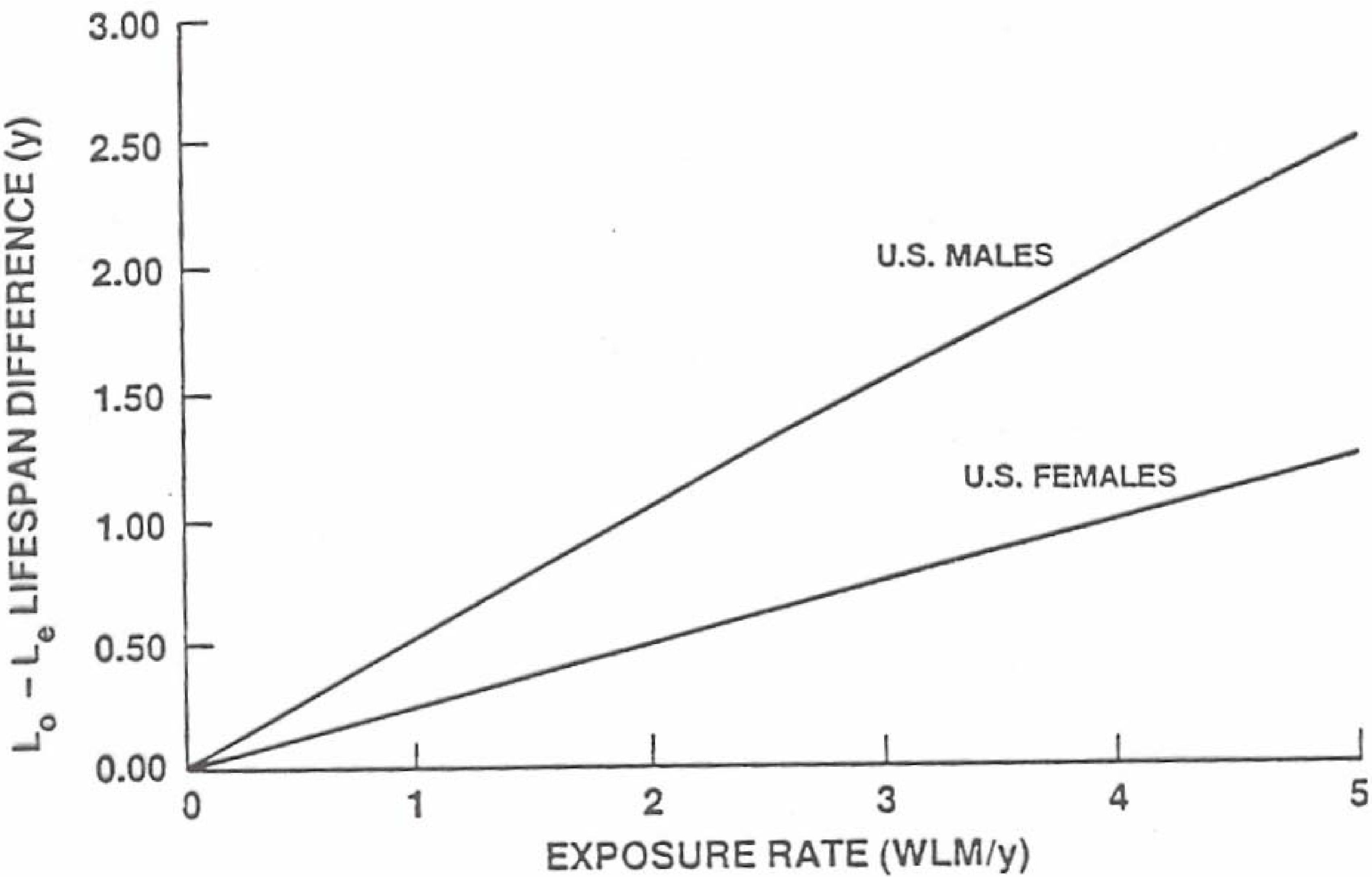
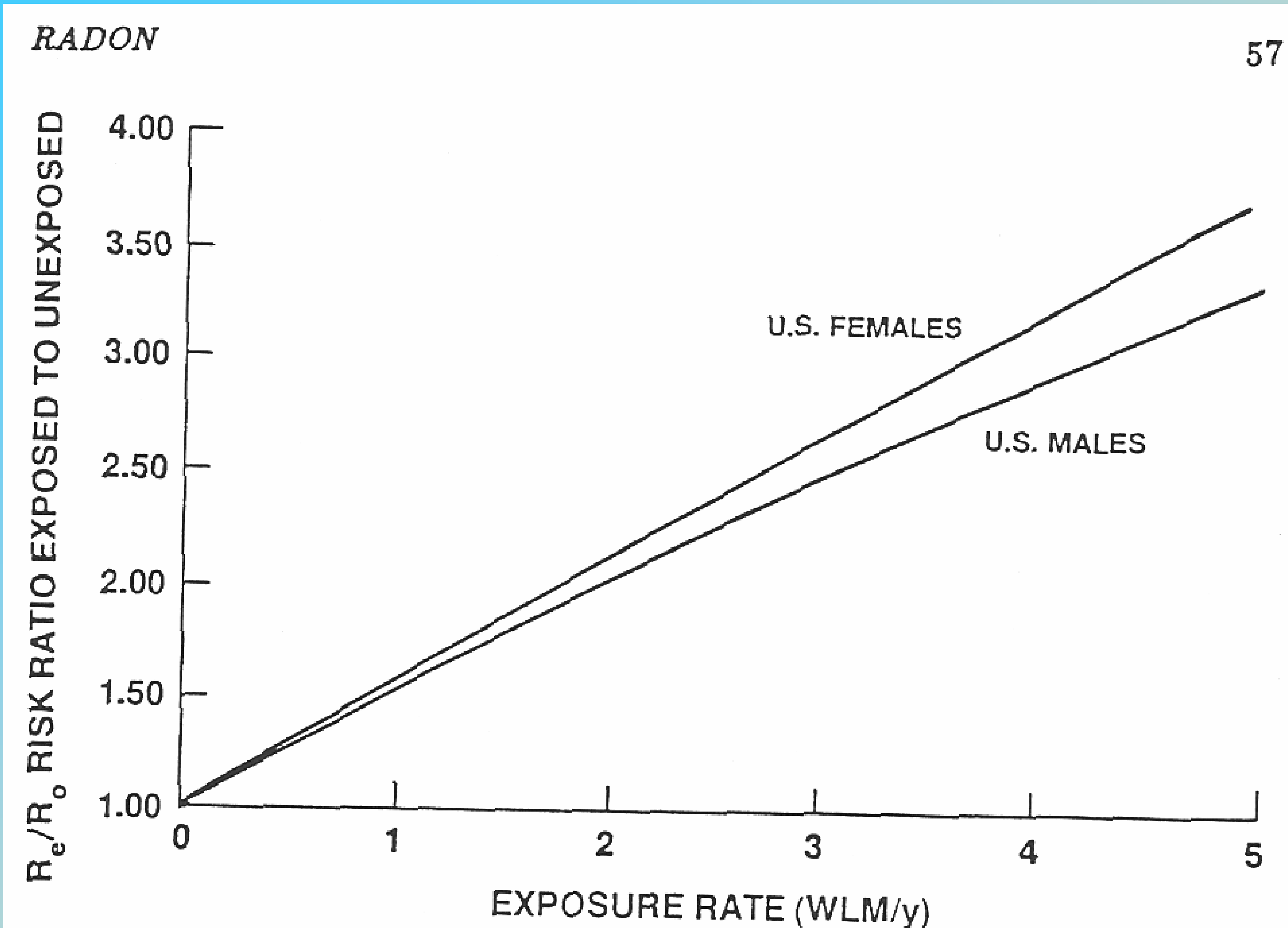
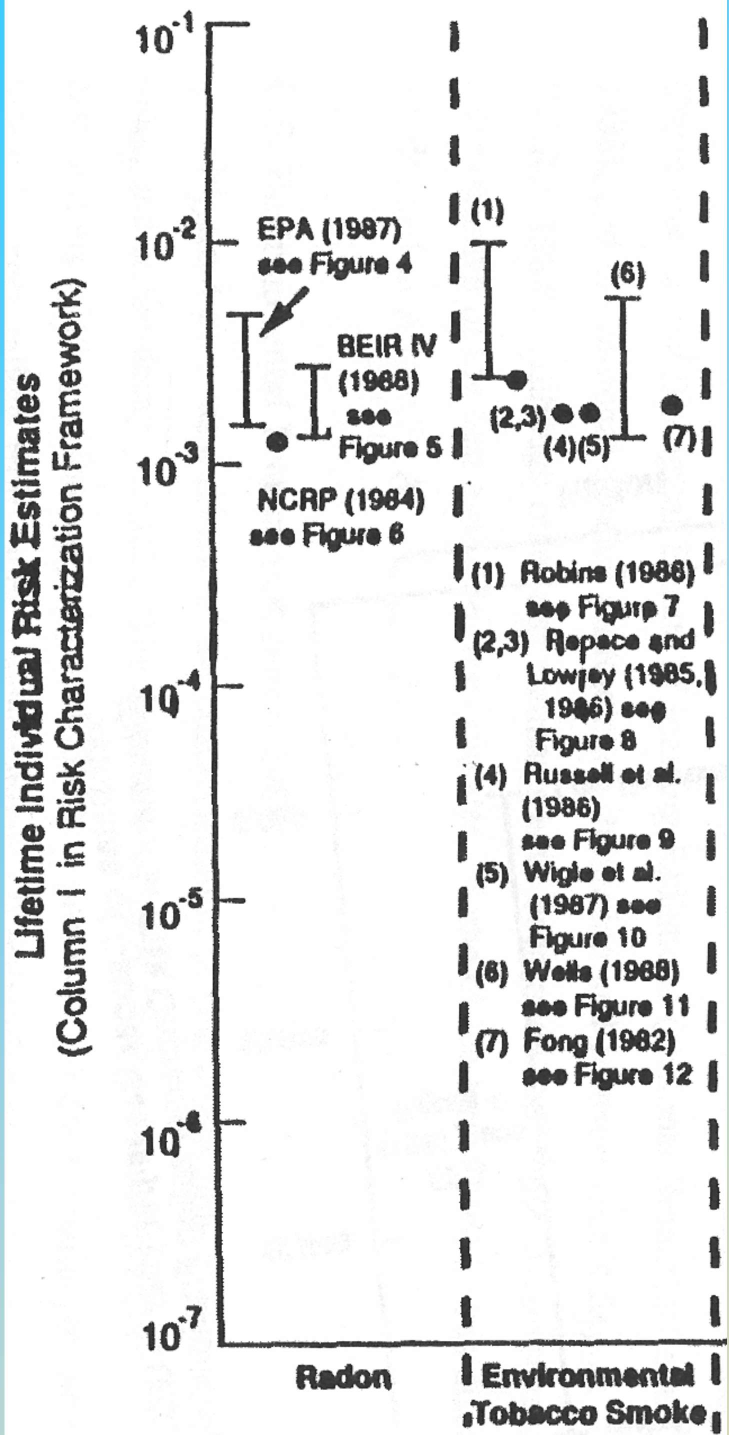


Figure 2-2. Risk ratio (R_e / R_o) of lung-cancer mortality for life exposure to radon progency at constant rates of annual exposure.





EPA
Indoor Air-Assessment:

A Review of Indoor Air Quality Risk Characterization Studies: United States 1989-1990.

< Comparison of Individual Lifetime Cancer Risk due to Indoor Air Pollutants

Figure 2. “ Indoor Air- Assessment” EPA. 1991

Comparison of Annual Cancer Cases due to Indoor Air Pollutants

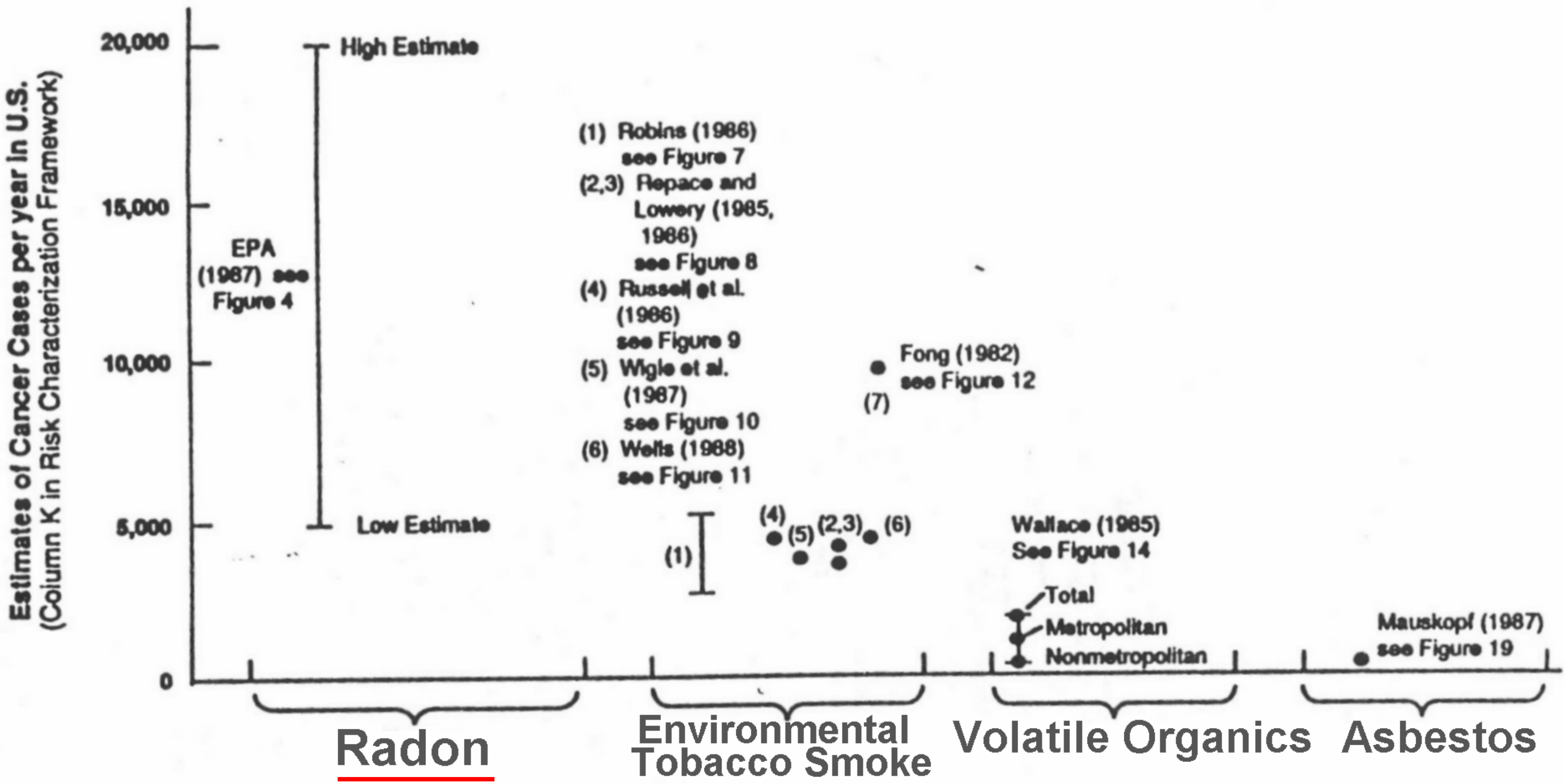
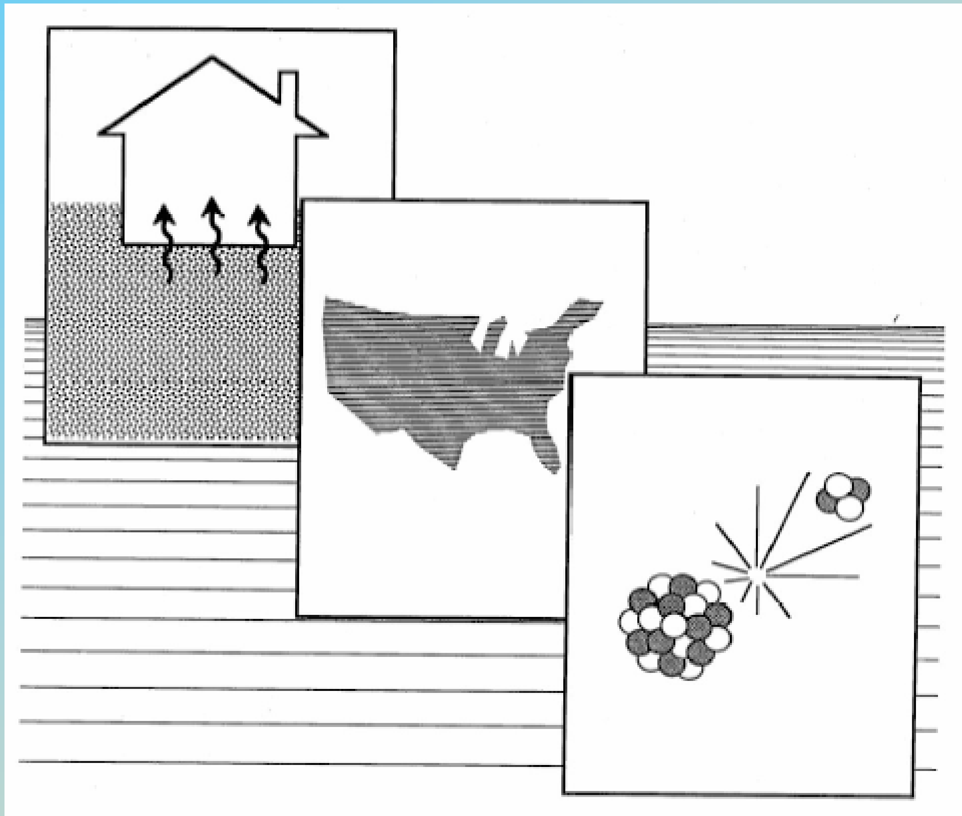


Figure 3. " Indoor Air- Assessment" EPA. 1991

EPA Assessment of Risks from Radon in Homes



EPA Assessment of Risks from Radon in Homes, 2003. http://www.epa.gov/radiation/docs/assessment/402-r-03-003.p

Table 5: Estimated number of lung cancer deaths in the U.S. in 1995 attributable to indoor residential radon progeny exposure (NAS 1999).

Smoking Status	Lung Cancer Deaths	Radon-Attributable Lung Cancer Deaths	
		Concentration Model	Duration Model
Males			
Total	95,400	12,500	8,800
Ever smokers	90,600	11,300	7,900
Never smokers	4,800	1,200	900
Females			
Total	62,000	9,300	6,600
Ever smokers	55,800	8,300	5,400
Never smokers	6,200	1,700	1,200
Males and Females			
Total	157,400	21,800	15,400
Ever smokers	146,400	18,900	13,300
Never smokers	11,000	2,900	2,100

EPA Assessment of Risks from Radon in Homes, 2003. http://www.epa.gov/radiation/docs/assessment/402-r-03-003

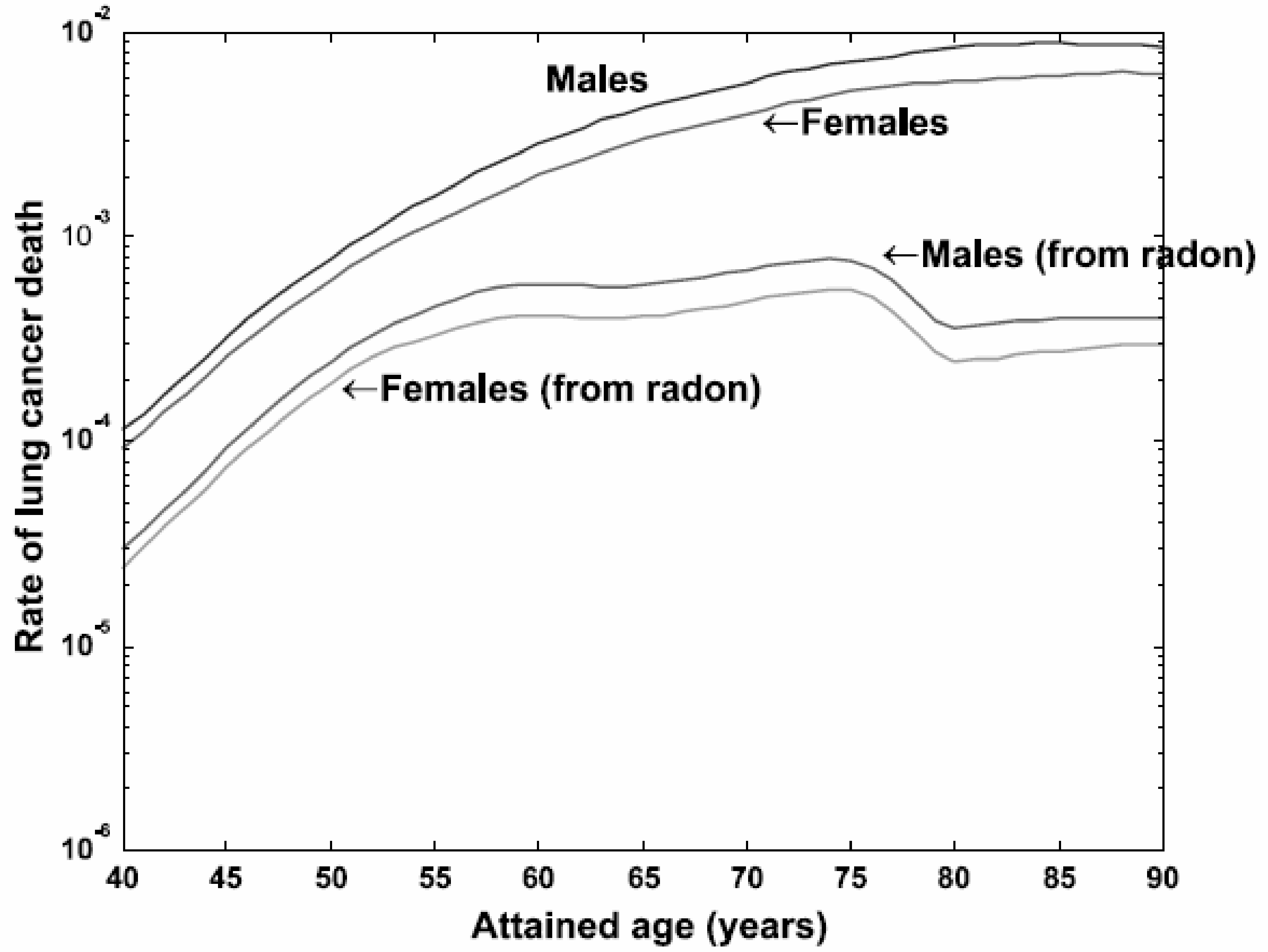


Figure 4: Rates of lung cancer death for ES males and females. Estimated rates of premature lung cancer death due to a constant exposure to radon of 0.181 WLM/y are also shown. EPA Assessment of Risks from Radon in Homes, 2003. http://www.epa.gov/radiation/docs/assessment/402-r-03-003

EPA Assessment of Risks from Radon in Homes, 2003. http://www.epa.gov/radiation/docs/assessment/402-r-03-003

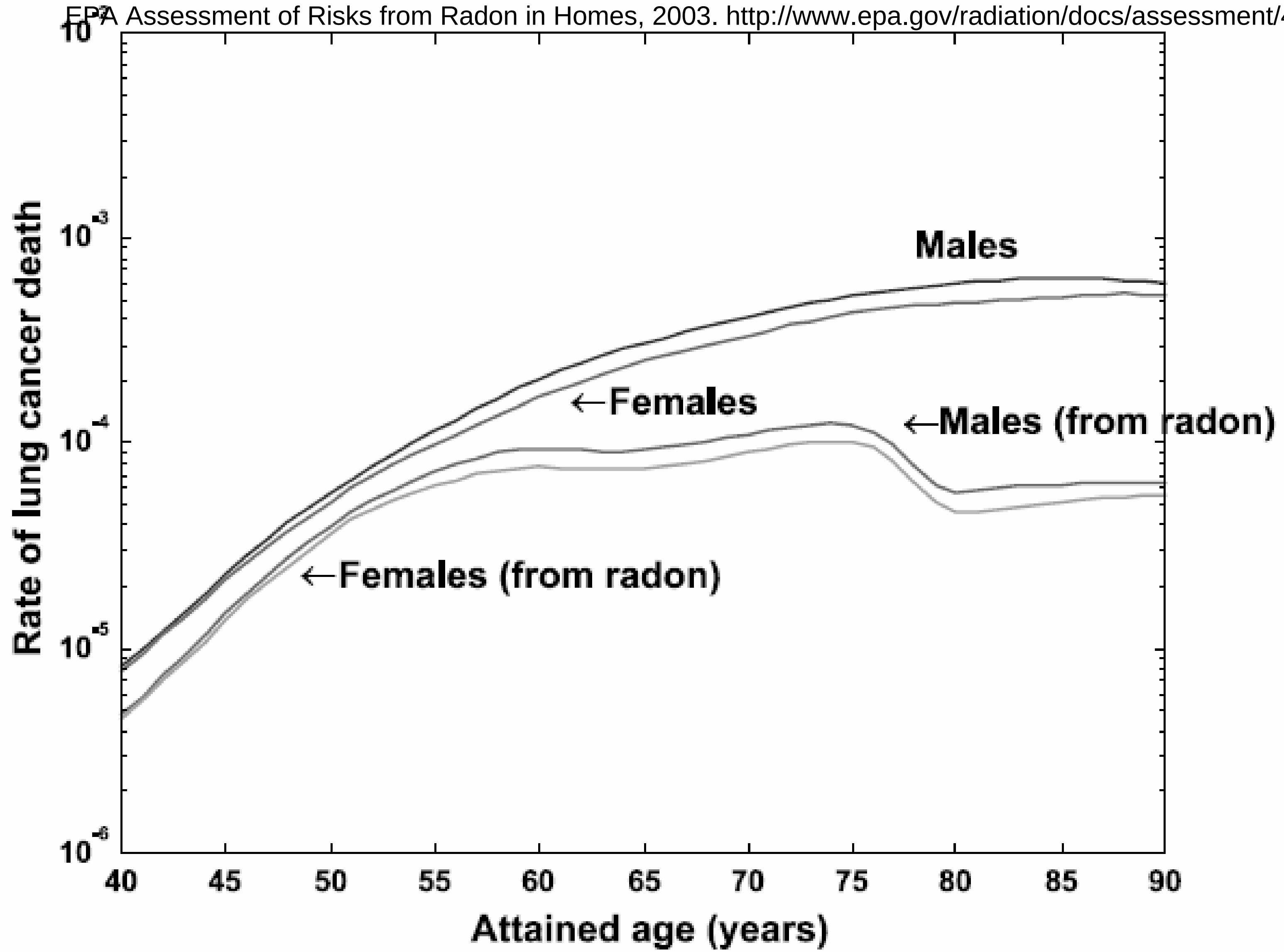


Figure 5: Rates of lung cancer death for NS males and females. Estimated rates of premature lung cancer death due to a constant radon exposure at rate 0.181 WLM/y also shown.

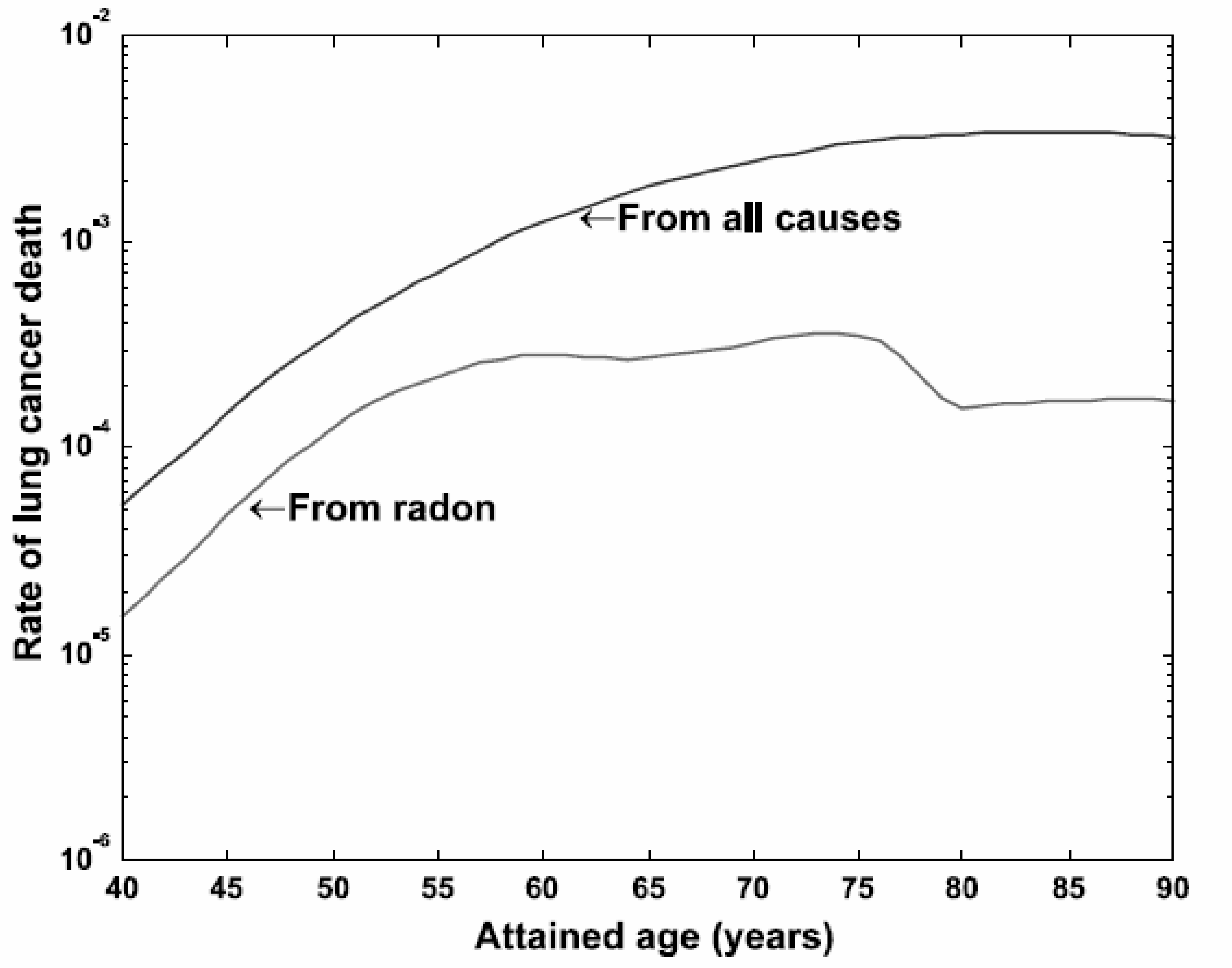


Figure 6: Rates of lung cancer deaths for a stationary population in which 53% of males and 41% of females are ES. Rates of premature lung cancer death due to a constant radon exposure at rate 0.181 WLM/y also shown.

EPA Assessment of Risks from Radon in Homes, 2003. http://www.epa.gov/radiation/docs/assessment/402-r-03-003

Table 10: Estimates of risk per WLM by smoking category and gender for a stationary population in which 53% of males and 41% of females are ES.

Gender	Smoking Category	Risk per WLM[a] (10^{-4})	Expected Life Span[a] (years)
Male	ES	10.6	71.5
	NS	1.74	72.8
	ES and NS	6.40	72.1
Female	ES	8.51	78.0
	NS	1.61	79.4
	ES and NS	4.39	78.8
Male & Female	ES	9.68	74.2
	NS	1.67	76.4
	ES and NS	5.38	75.4

[a] Based on 1990 adult (ages ≥18 y) ever-smoking prevalence data (58.7% males and 42.3% females are ES) and assumption that 37% (males) and 36% (females) of children (ages < 18 y) will become ES.

EPA Assessment of Risks from Radon in Homes, 2003. http://www.epa.gov/radiation/docs/assessment/402-r-03-003

EPA Assessment of Risks from Radon in Homes, 2003. http://www.epa.gov/radiation/docs/assessment/402-r-03-003

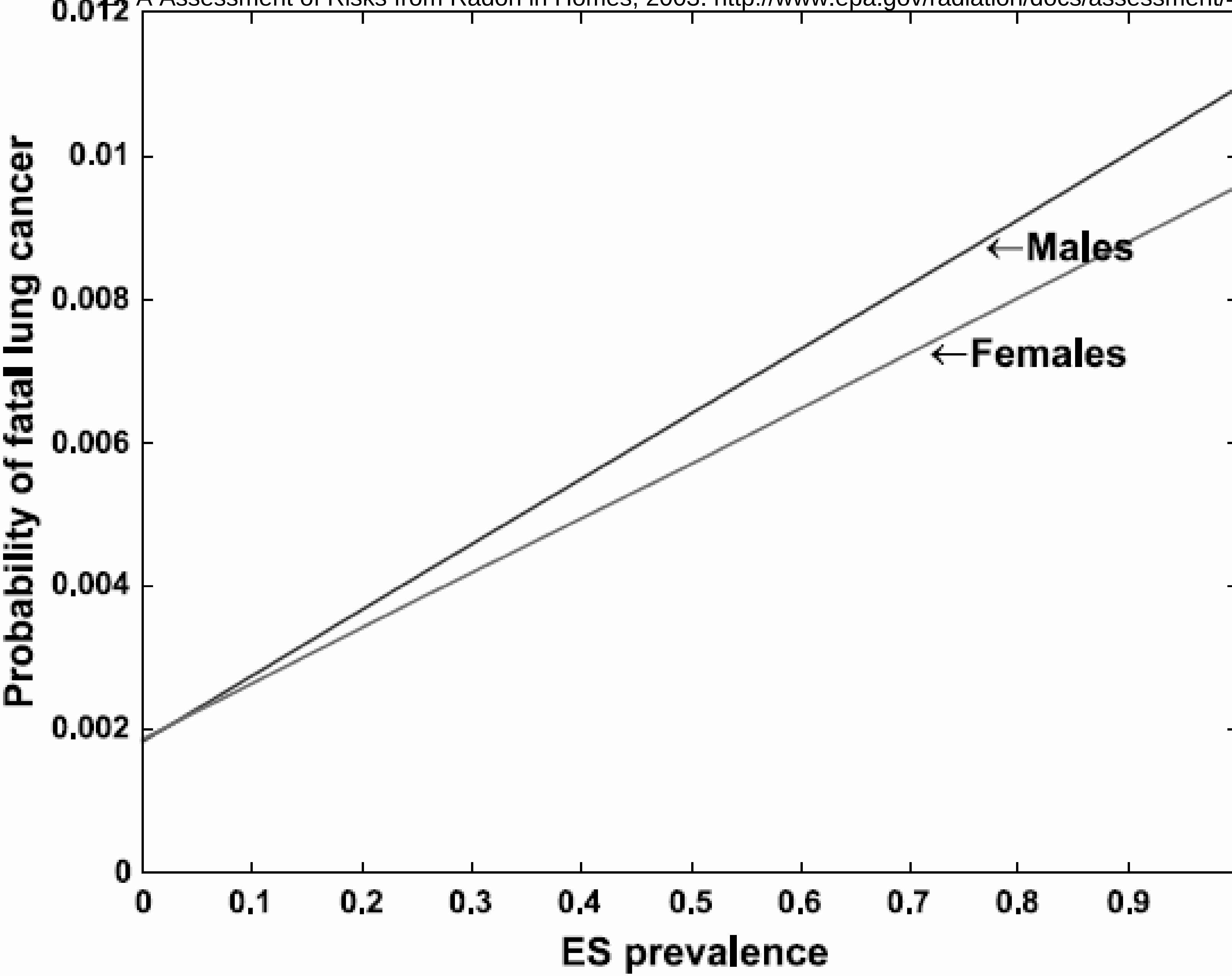


Figure 8: Probability of a premature lung cancer death from a lifelong exposure to radon at 1 pCi/L as a function of ES prevalence.

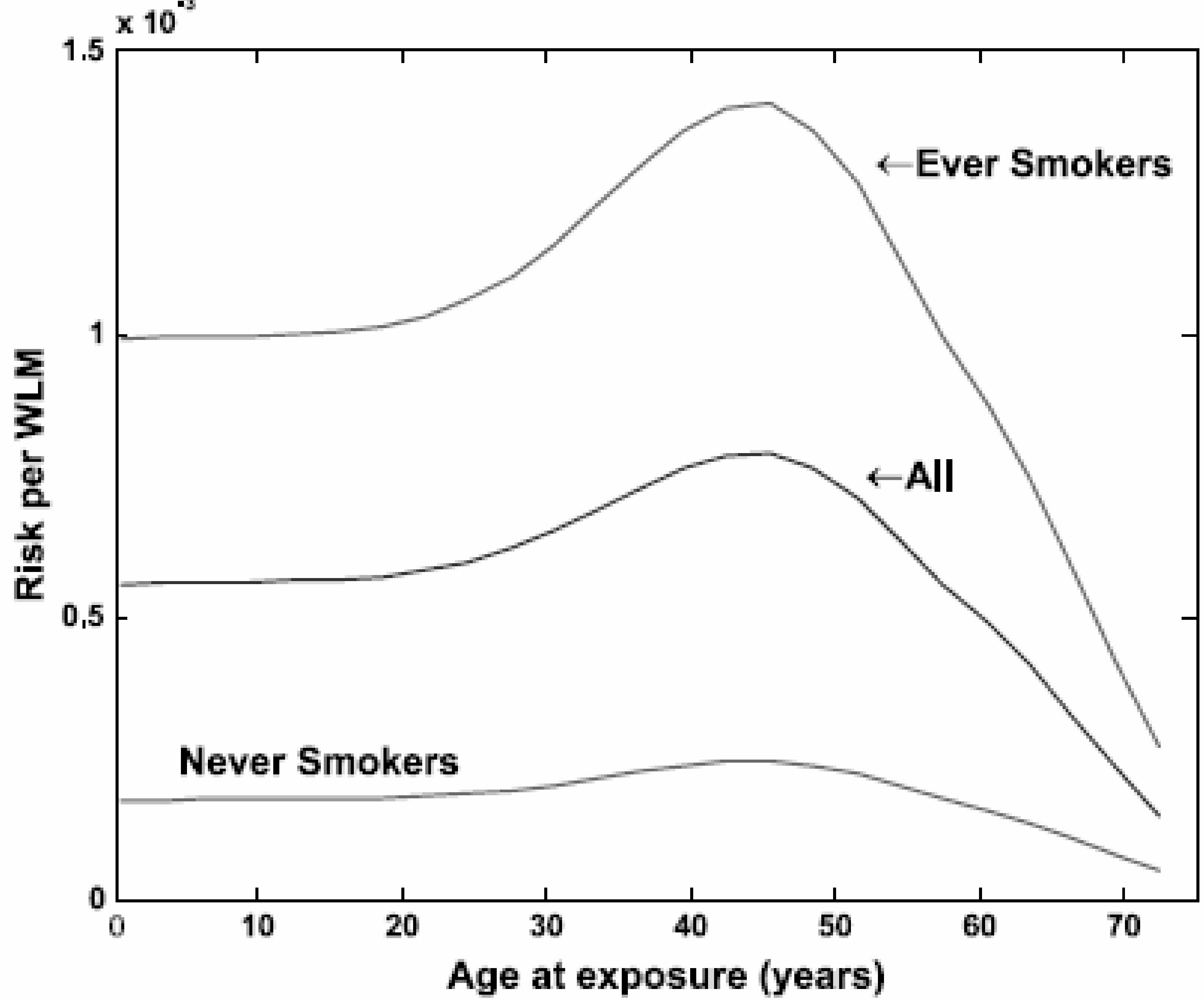


Figure 9: Risk per WLM as a function of age at exposure.

EPA Assessment of Risks from Radon in Homes, 2003. http://www.epa.gov/radiation/docs/assessment/402-r-03-003

How did they arrive at these numbers?

- Took Rn levels in mine, plotted this versus the average lifetime risk of dying from lung cancer (but most smoked as well, which gives a huge variation).
- The statistics are horrible → can't do controlled experiments, therefore must use convenience data to generate risk for average risk in home.
- Also, plot of [Rn] vs. Infiltration rate. Where do you draw levels for remediation? At mean? (save 1% population) or above that limit? (expensive to remediate, 5- 10% saved).

Risk assessment and public perception:

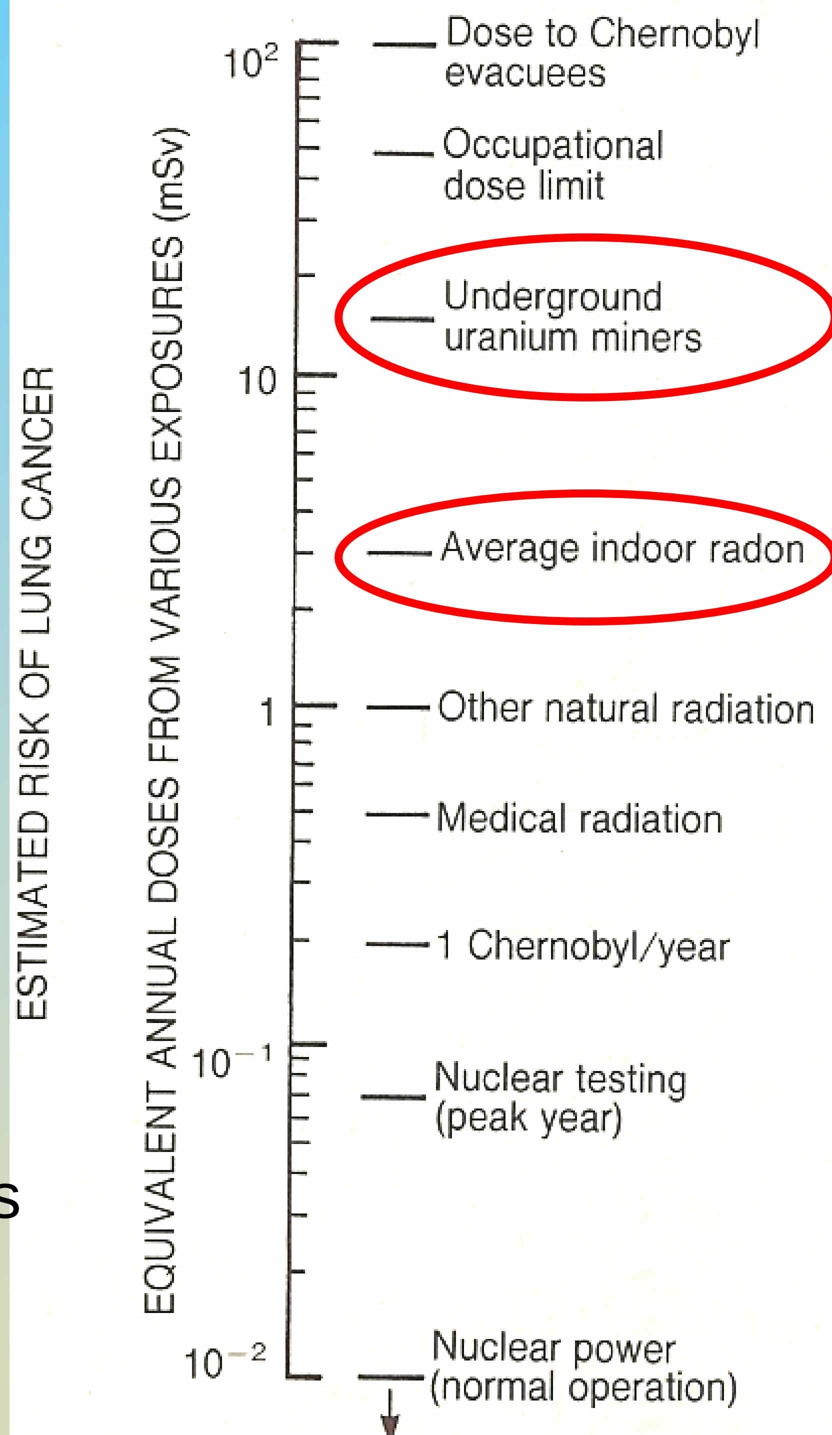
- **Smoking enhances the risk with U mining or Rn damage.**
- If you don't smoke, differences → .1 - .5% low vs. high Rn

- 20 years at 20 pCi/L (non-smoker) → .5% risk
- 20 years at 20 pCi/L (smoker) → 35% risk
- (smoking alone is 25% risk).

http://bbsnews.net/dailys/tobacco.phtml

What do the different exposures mean in terms of cancer risk?

- **Average exposure → .5% lung cancer risk**
- **Uranium mining → 5% incidence death from lung cancer.**



Estimates of lung cancer risk for > lifetime occupancy. Radiation doses from other sources are indicated for comparison. Nero "Earth, Air, Radon and Home," 1989

Ways to solve

1. Put positive pressure inside house with outside air to change flow system so that Rn can't flow in. This is expensive, and not certain if it is effective.

2. Doesn't work, but try to pump Rn away before it enters house. Also expensive.

- **Reasonable risk assessments - don't even have a reasonable baseline.**

Removal rates of particles by commercially available devices

The effectiveness depends substantially on the type of device used. For some devices the flow rates and the effective rates at which the air is cleaned are comparable to ventilation rates: for a house with a volume of 300m3, a ventilation rate of 0.5hr-1 is equivalent to 150m3/hr. However, the more popular, less expensive devices, typically panel filters, have little effect on concentrations of either particles or decay products.

Nero “Earth, Air, Radon and Home,” 1989