Perspectives on Unresolved Issues with Radon

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National Mining Association (NMA)

/Nuclear Regulatory Commission (NRC)
Uranium Recovery Workshop

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Presented By:

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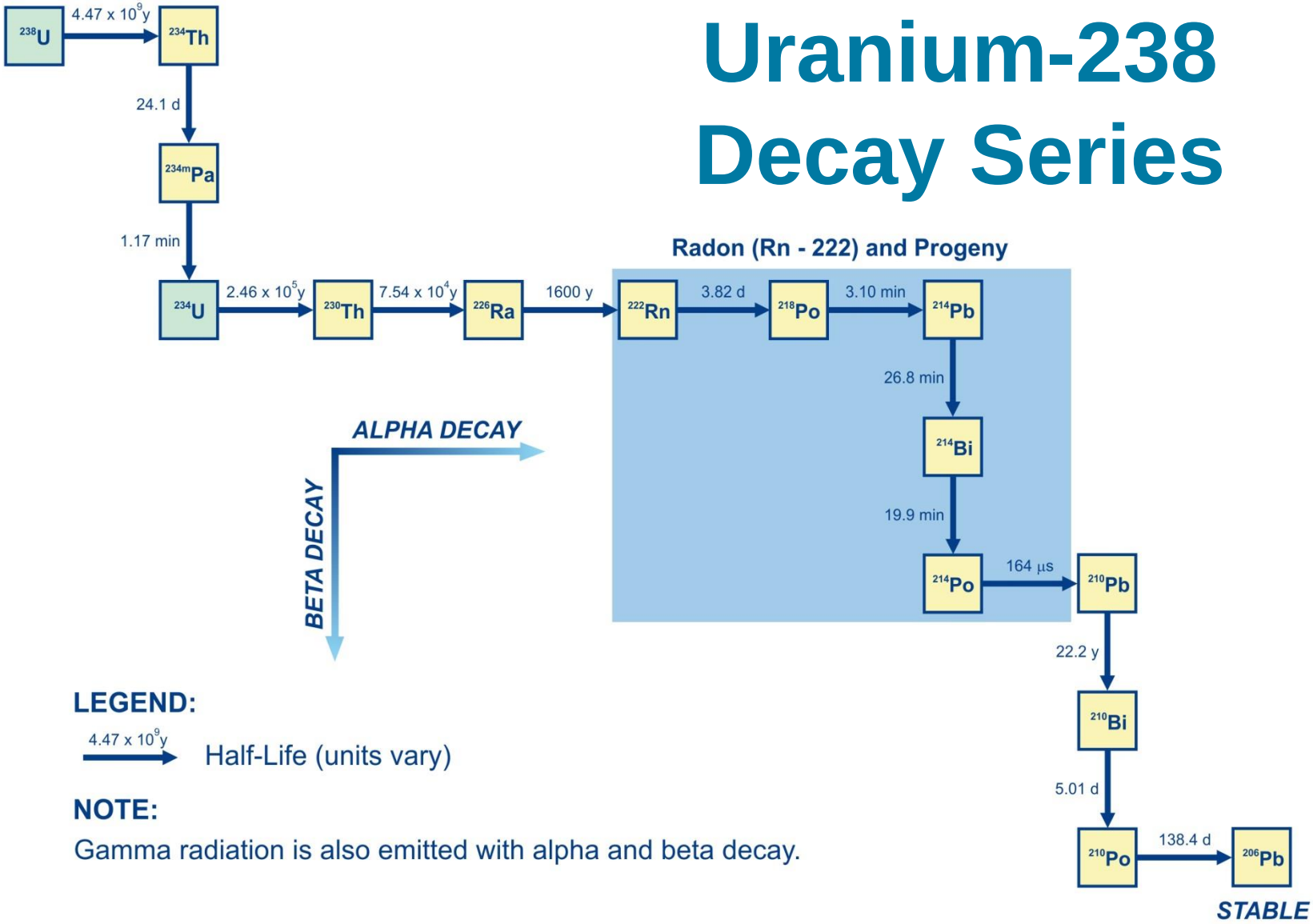
OUTLINE

- About Radon
- Radon from Mill Tailings
- Radon From Water (Evaporation) Ponds
- Regulatory Framework
- Technical Basis – the 20 pCi/m2-sec standard
- Radon and ISRs
- Main Conclusions

Radon -222 [Radon]

- Radon is natural and is everywhere in the environment due to exhalation from rocks and soils
- Radon is a radioactive noble gas decaying to solid atoms
- Radon is produced through radioactive decay of Ra-226 with a half-life of 3.82 days
- Levels of radon are highly variable

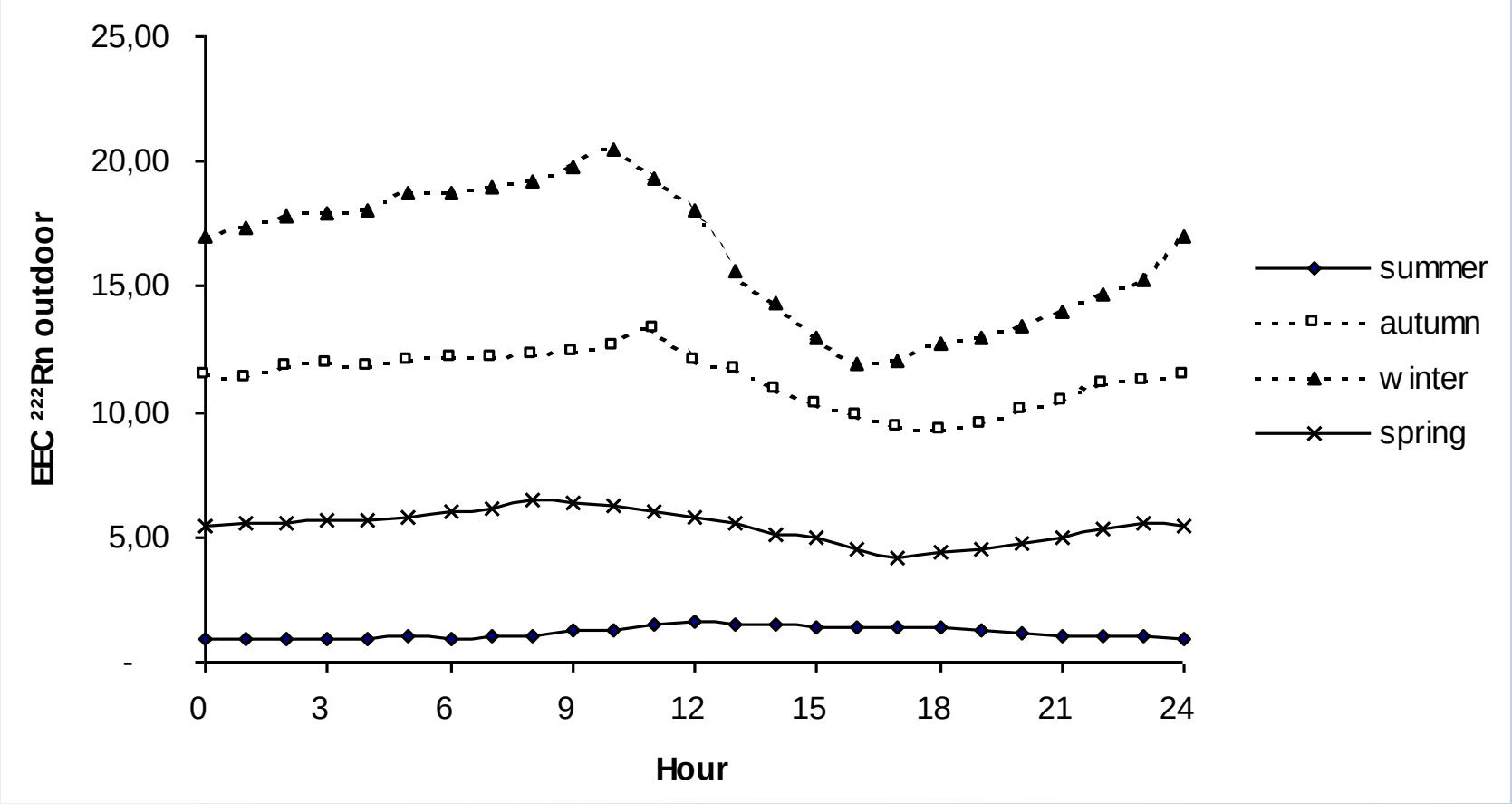
Uranium-238 Decay Series



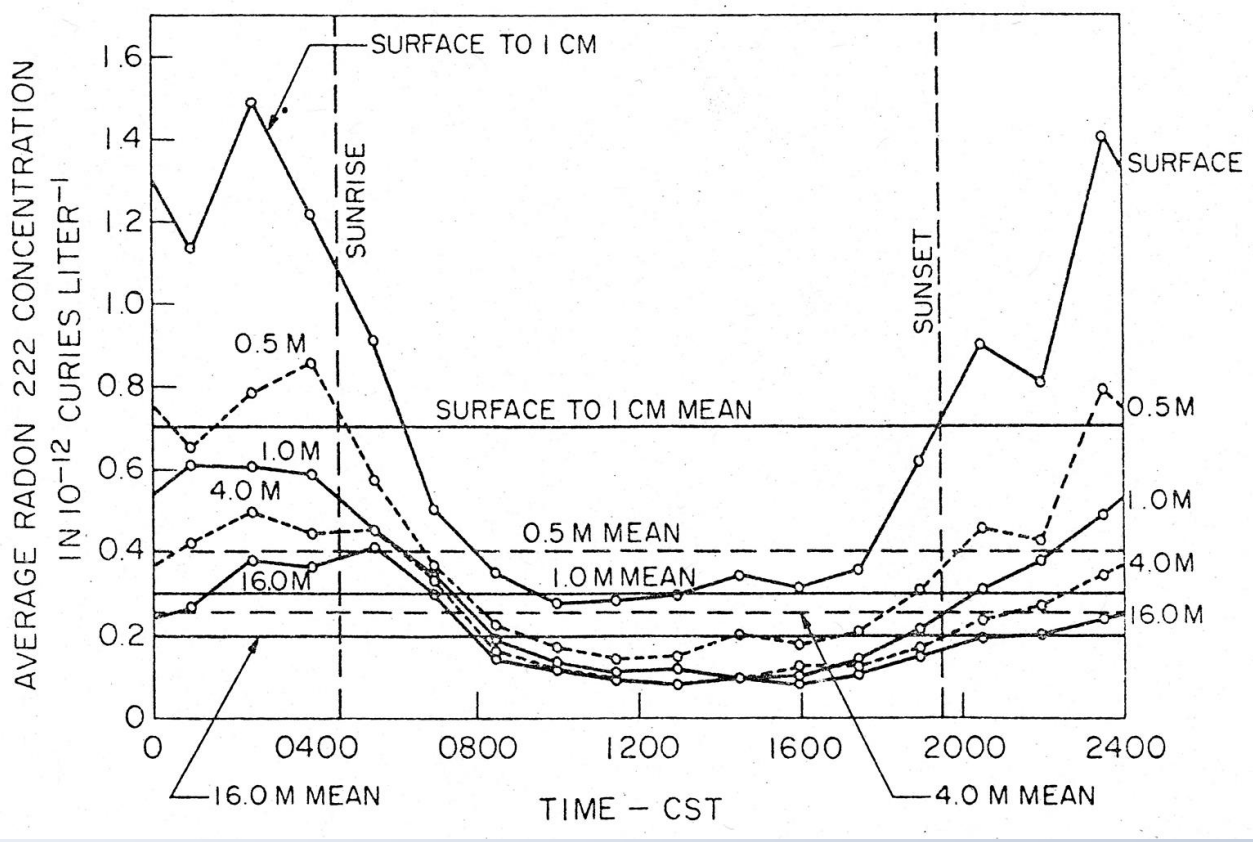
Typical Levels of Radon
[from UNSCEAR 2000 and UNSCEAR 2006 Annex E]

- **Ranges based on:**
  - UNSCEAR surveys in 2001, 2004 & 2006
  - Reports of national authorities presented by delegates to UNSCEAR
  - Scientific (Peer Review) literature
- **“typical” outdoor levels**
  - 10 Bq/m^3 (1- 100 Bq/m^3)
  - 0.27 pCi/L (0.027-2.7pCi/L)

Annual Variability in Rio de Janeiro



Rn-222 Concentration Diurnal Variation



SOURCE: After Pearson, U.S. Department of Health & Welfare, 1967

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Subpart W
NESHAP for Radon Emissions from Operating Mill Tailings

- *Uranium byproduct material or tailings* means waste produced by the extraction or concentration of uranium from any ore processed primarily for its source material content.
- **Rn-222 flux from "existing" (pre 1989) uranium mill tailings pile of less than 20 pCi/m^2 - s**
- Will address Subpart W requirements in more detail later

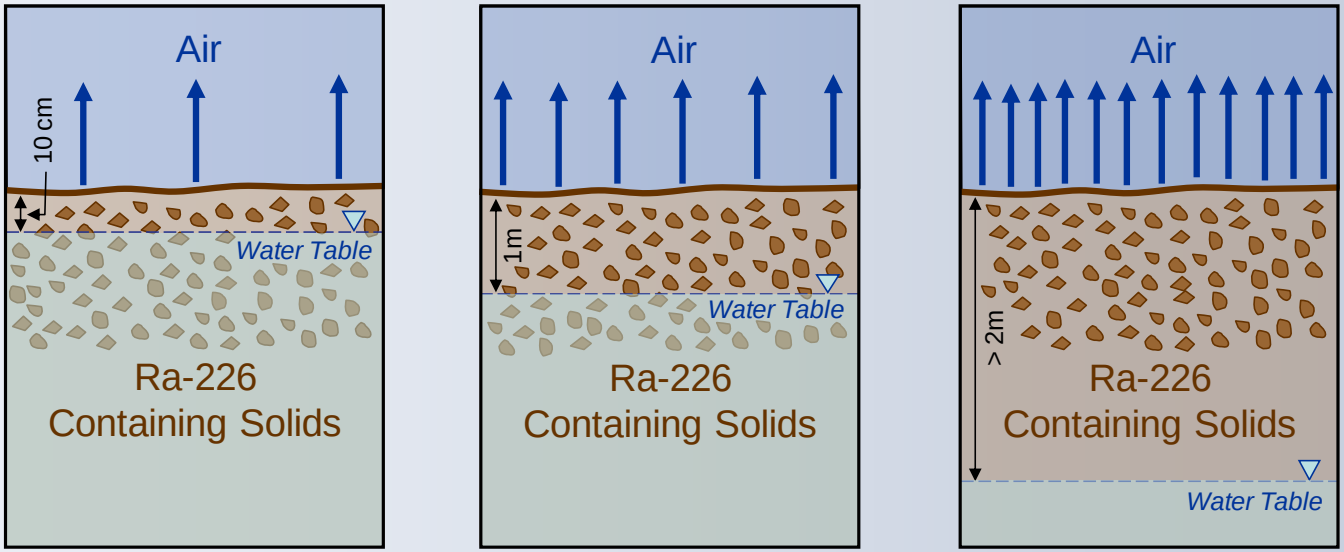
Nominal Radon Flux - Mill Tailings

(BID – Final Rule for Radon, EPA 1986)

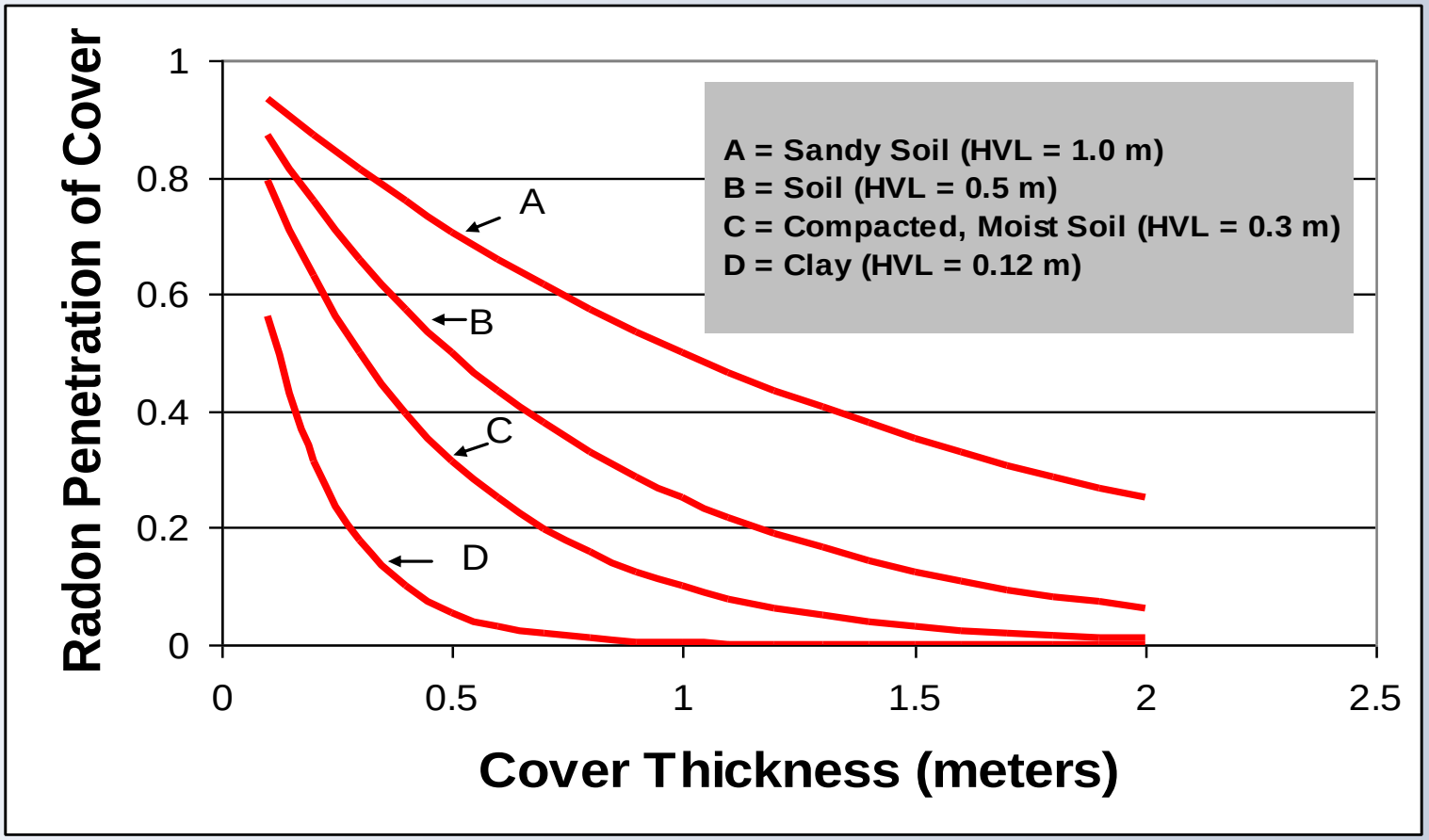
- Dry Tailings (soil) 1 pCi Rn-222/m^2s per pCi Ra-226/g
- Saturated 0.3 pCi Rn-222/m^2s per pCi Ra-226/g
- Water Cover 0 pCi Rn-222/m^2s per pCi Ra-226/g

Dewatering and Radon Flux

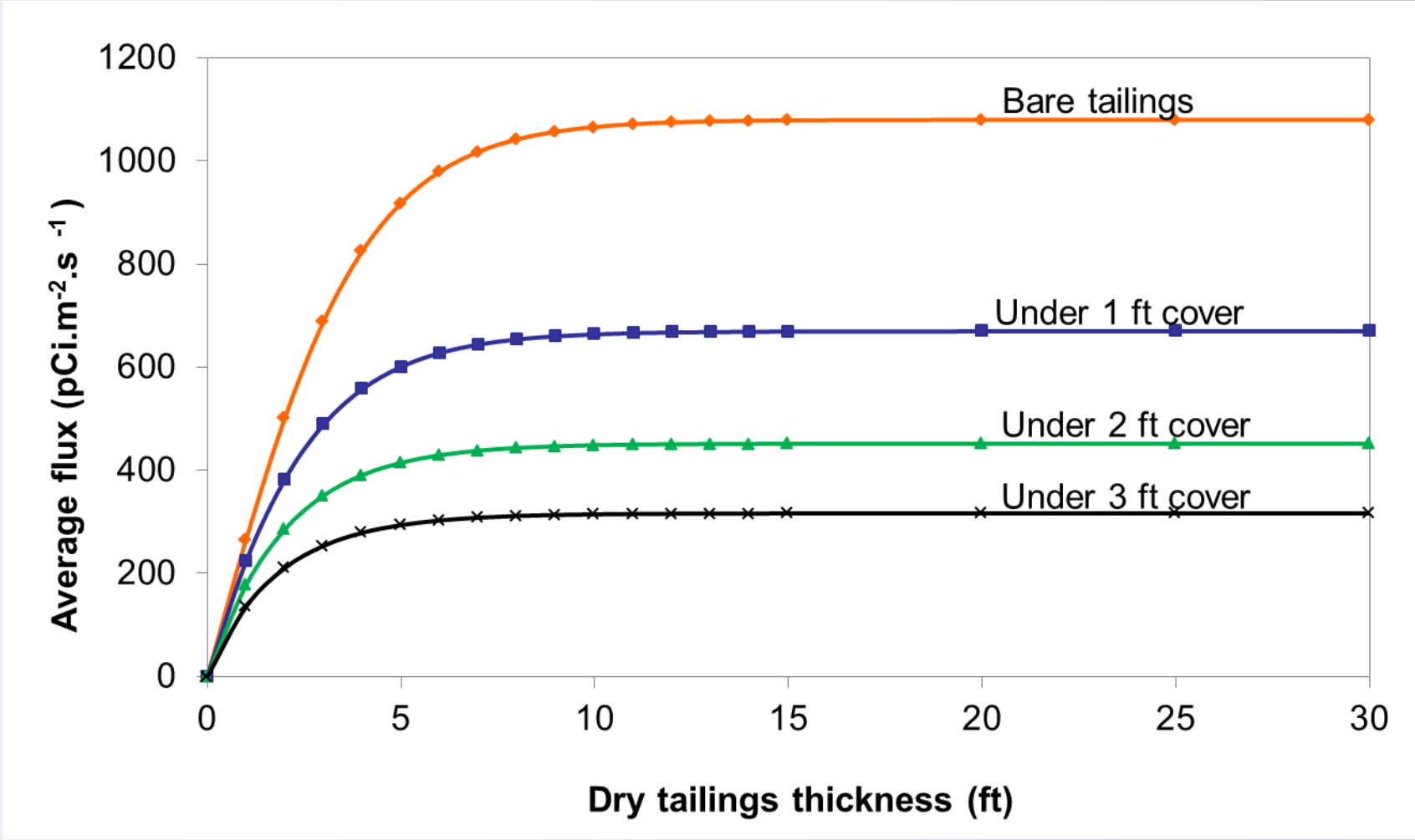
- As the Water in Pores is Replaced with Air, More Radon Becomes Available for Exchange With Air, as Radon is Better Able to Diffuse Through the Tailings to the Air/Tailings Surface



Diffusion of Radon Across a Medium



Radon Flux (grade of 0.4%U)



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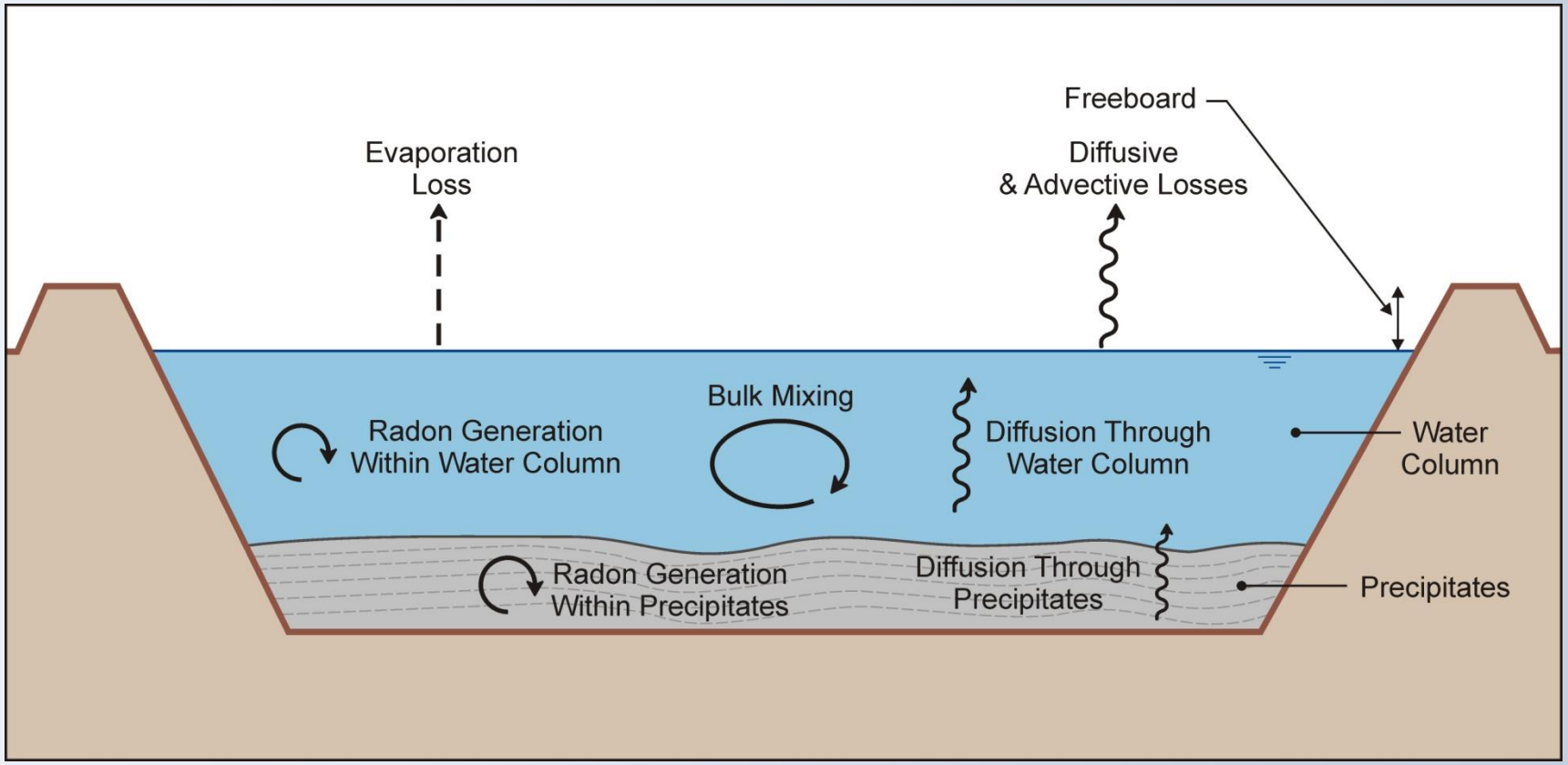
Radon From Water (Evaporation) Ponds - Release Mechanisms



Evaporative and Diffusion Emission

- A 2010 analysis by SENES* (for conventional mill recently licensed by Colorado) showed that evaporative loss of ponds is extremely insignificant compared to diffusional release of radon
- The SENES calculations indicated that the total radon emission from evaporation is insignificant
- Diffusion through water is insignificant due to very small diffusion coefficient in water - decays before it can get out !

* USEPA @ http://www.epa.gov/radiation/docs/neshaps/subpart-w/evaporationpondsrnfluxanalysis083010

Radon releases from water ponds are small

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40CFR61 Subpart W – Operating Mill Tailings

- Tailings impoundments built prior to December 15, 1989 must monitor for radon flux during operations (Method 115) and shall not exceed 20 pCi/m^2-sec. (One operating facility “pre 1989” in US)
- Tailings impoundments built after December 15, 1989 must comply with one of two Performance Standards

40CFR61 Subpart W – Some Definitions

(1) Phased disposal – disposal of tailings in lined tailings impoundments that are no more than 40 acres in area. No more than two impoundments, including existing impoundments, in operation at any one time.

(2) Continuous disposal – disposal of tailings such that tailings are dewatered and immediately disposed with no more than 10 acres uncovered at any time and operated in accordance with 40CFR 192.32(a) as determined by the Nuclear Regulatory Commission.

"Dewatered" – removal of water from recently produced tailings such that the water content does not exceed 30% by weight.

"Operational" – the impoundment is being used for placement of new tailings or in standby and is in operation until the day that final closure begins.

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So what is technical basis and where does the 20 pci/m^2-s come from ?

- US EPA 1982. *Final EIS for Remedial Action Standards for Inactive U Processing Sites*; EPA 520/4-82 013-1

EPA 1982 Evaluated Implications of Various Flux Criteria

- EPA 1982 Evaluated implications (health risks, cover thickness, costs, etc) at 4 radon emission levels:
  A. 2 pCi/m^2-s: can't distinguish from BKG – eliminated
  B. 20 pCi/m^2-s: essentially BKG " off the pile"; only a concern if living on the tailings pile – chosen
  C. 100 pCi/m^2-s - did not meet NRC unrestricted area limit at the time of 3 pCi/l; required restricted access near the pile – therefore eliminated
  D. No requirement - eliminated as not protective

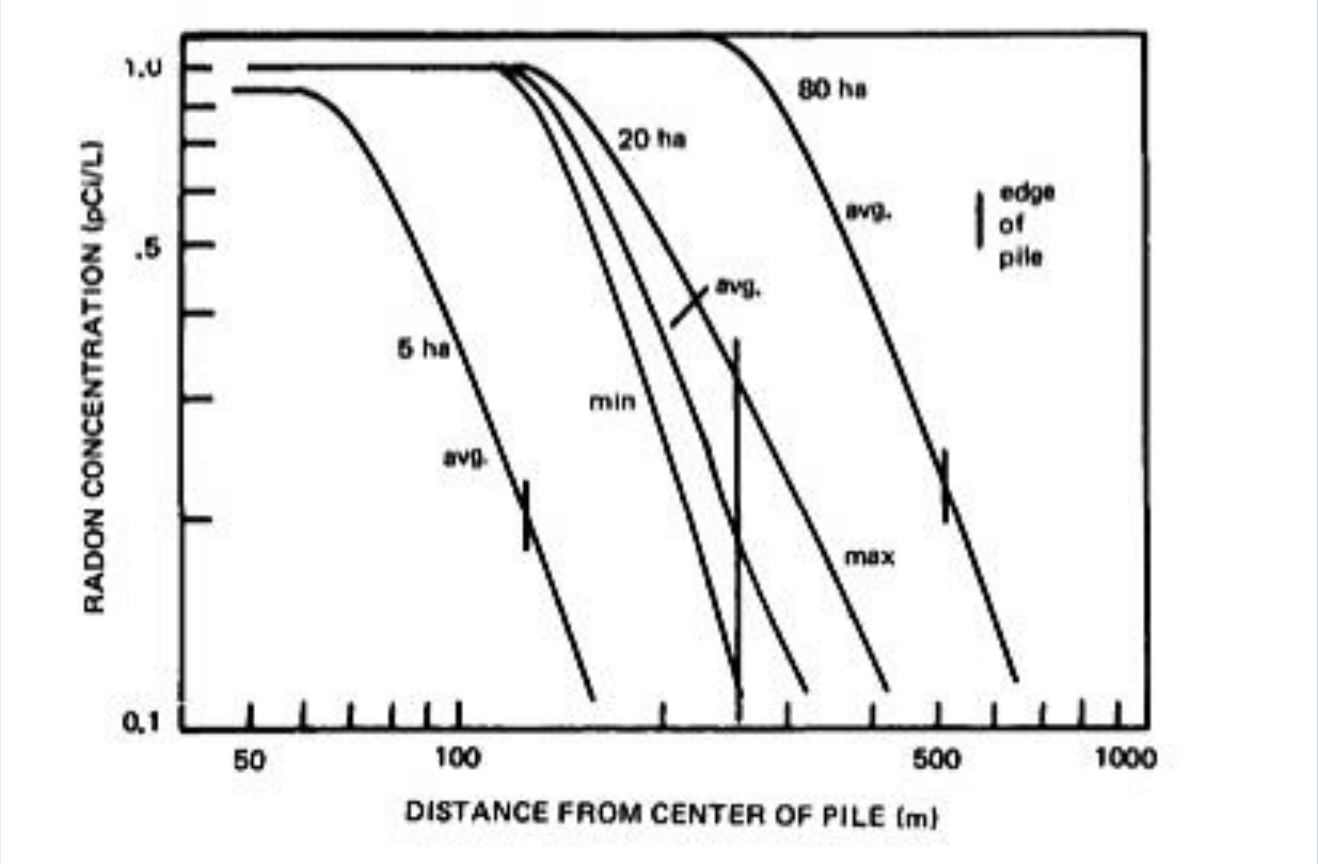
EPA NESHAPS 1989*

- Refers to the 20 pCi / m2 – sec as the "UMTRCA Standard" (40 CFR 192) and references EPA 1982
- Some interesting data from Vol. 2, Table 9- 6: *Estimated exposures and risks to individuals living near operable tailings impoundments*

State/Mill	Maximum Radon Concentration (pCi/l)	Maximum Exposure (WL)
Colorado		
Canon City	4.2E-3	1.7E-5
New Mexico		
Ambrosia Lake	2.7E-3	1.4E-5
Homestake	5.8E-2	1.9E-4
Texas		
Panna Maria	1.0E-1	3.0E-4
Utah		
White Mesa	2.2E-3	1.5E-5
Rio Algom	1.5E-3	6.4E-6
Shootaring	8.8E-4	3.8E-6
Washington		
Sherwood	4.8E-3	1.9E-5
Wyoming		
Lucky Mc	1.2E-3	8.4E-6
Shirley Basin	2.2E-3	1.6E-5
Sweetwater	6.1E-4	4.2E-6

**EPA /520/1-89-005; Risk Assessments Methodology, EIS, NESHAPS for Radionuclides*

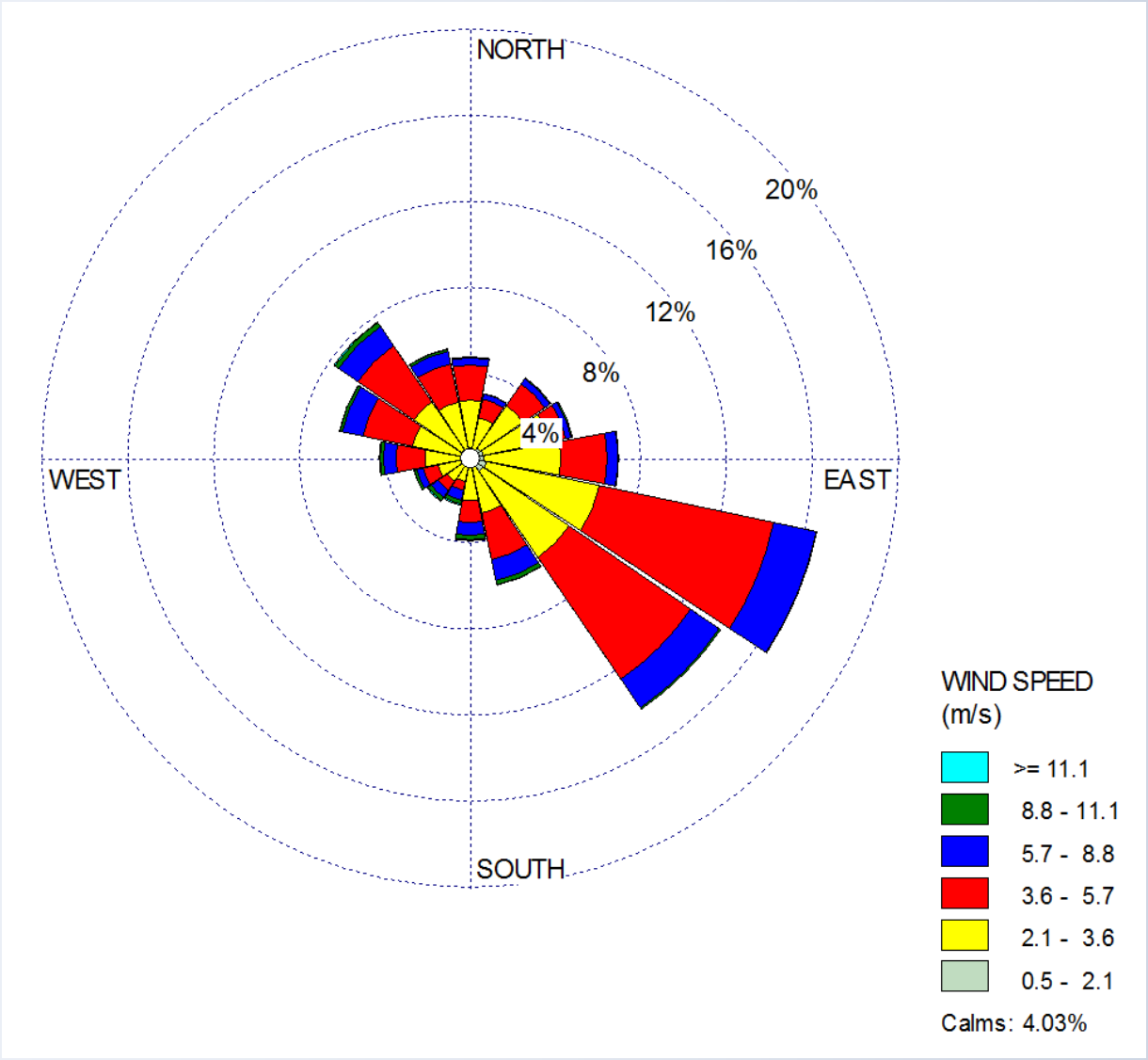
Radon Concentrations in Vicinity of Tailings from Flux of 20 pci/m2-sec



Source: US EPA 1982. Final EIS for Remedial Action Standards for Inactive U Processing Sites

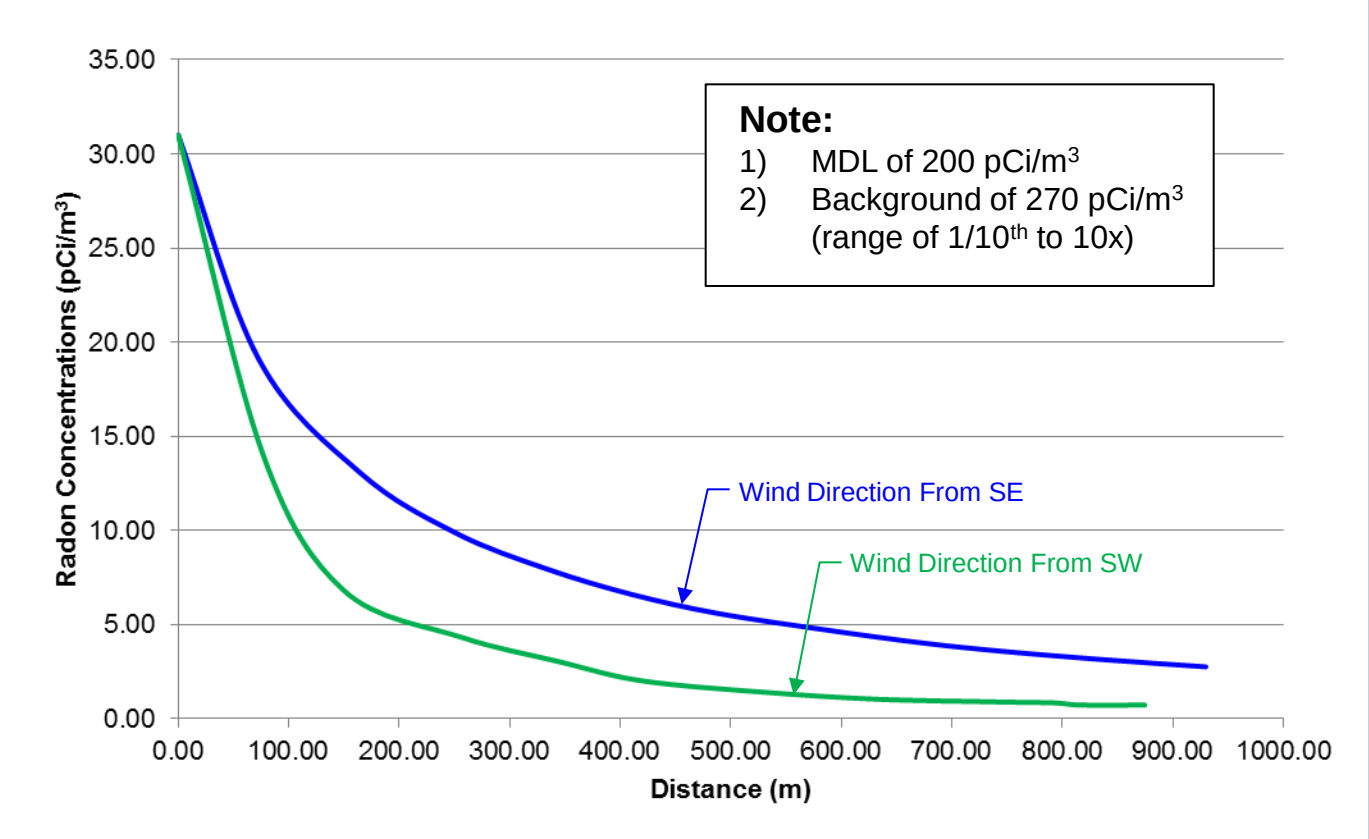
Incremental Radon Concentration is Essentially Background Within a Very Short Distance from Tailings Cell

Nominal Regional Wind Rose



Radon Concentrations from 40 Acre Tailings Cell

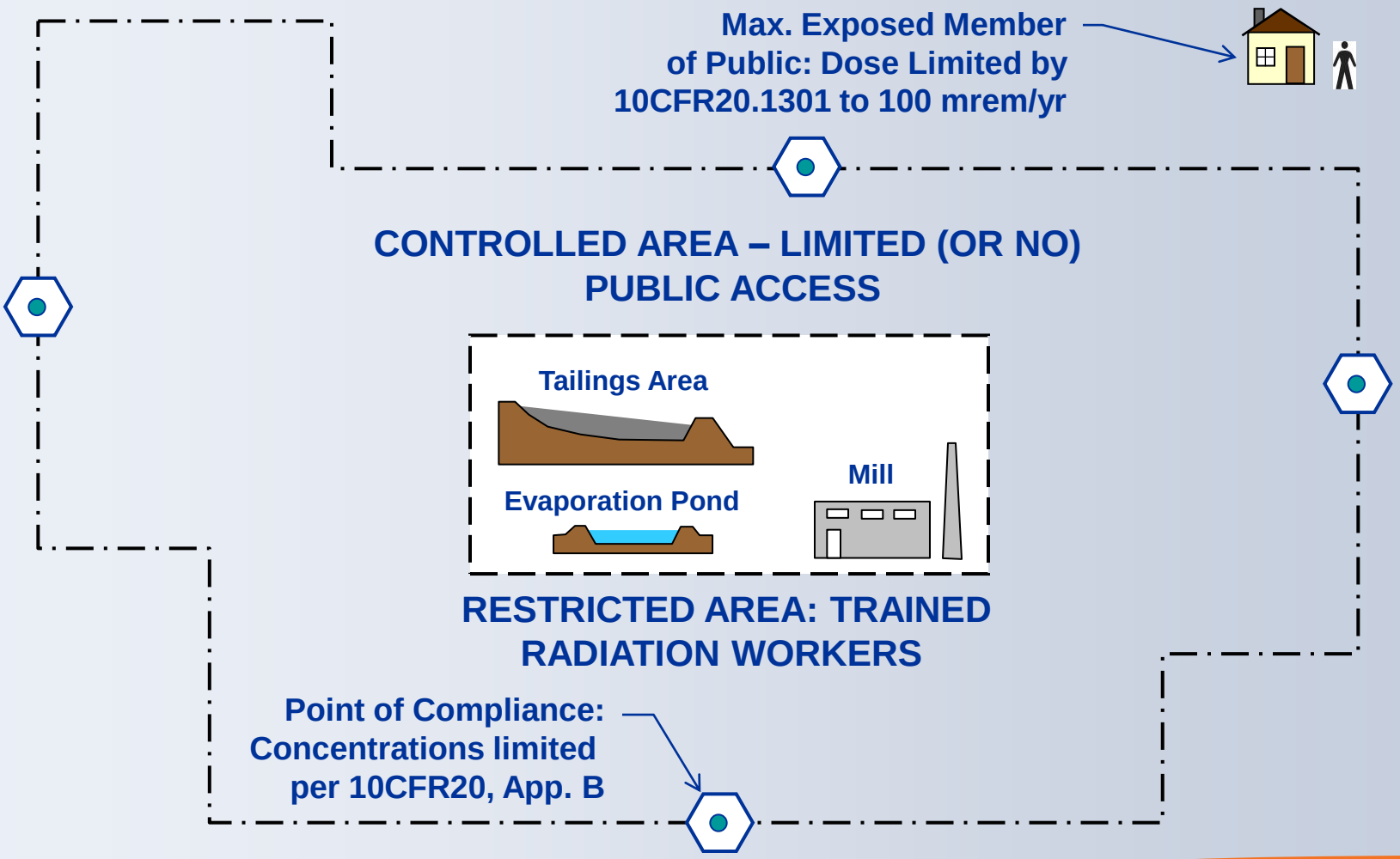
(releasing radon at 20 pCi/m²s; EPAs AERMOD Code)



What Does MILDOS-AREA Say:
Offsite Dose from a 20 pCi/m2-sec Flux – Input and Assumptions

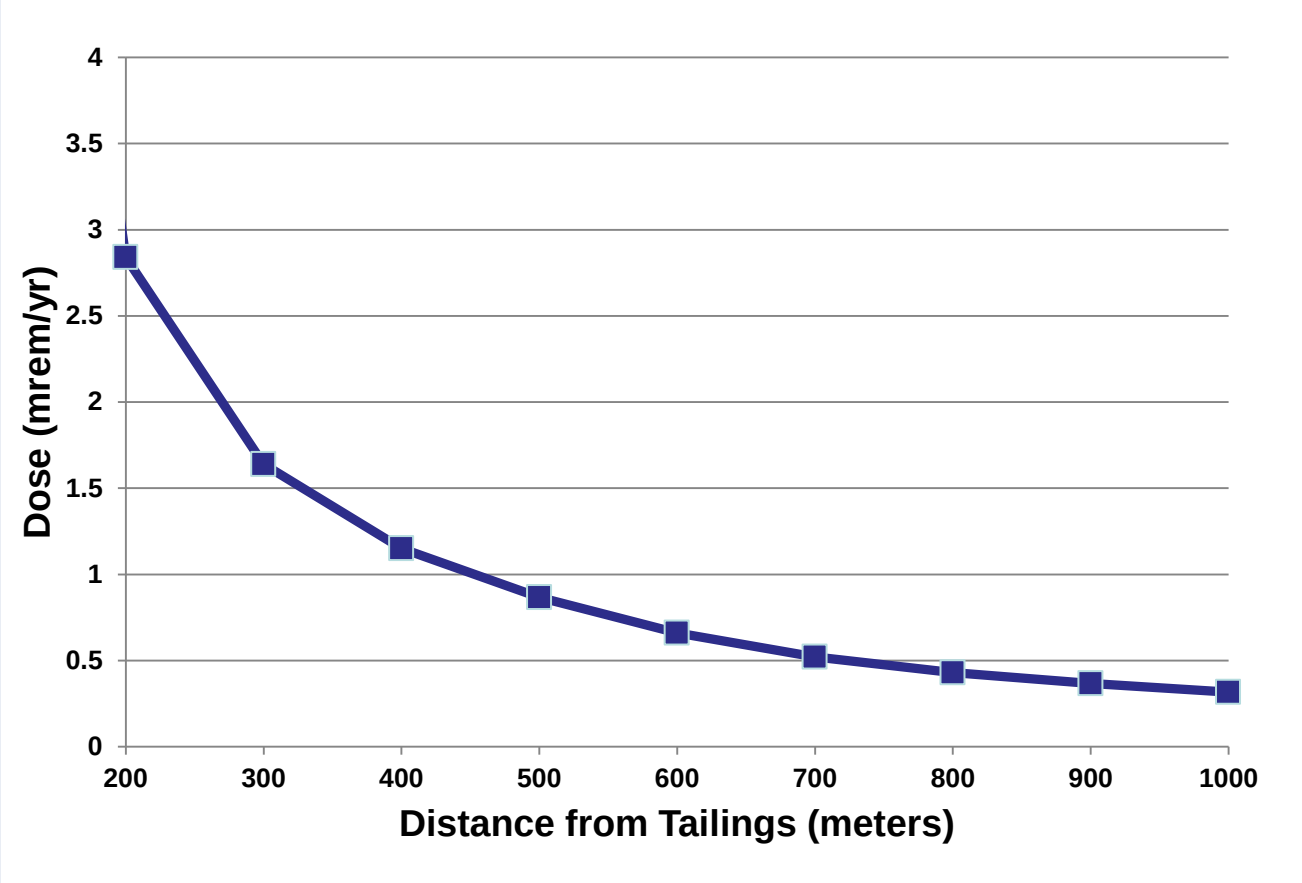
- Meteorological – Data set from current met station in Gas Hills; very similar to "West City" generic site used by NRC in 1980 GEIS
- Receptor – resident farming family, full time, no shielding, locally grown foodstuffs (MILDOS data for Wyoming)
- Source Term – 40 acres (400x400 m), 20 pCi/m2-sec, downwind in very predominant wind direction (SW/WSW – similar to NRC 1980)
- MILDOS estimates of Rn concentrations off pile very similar to EPA 1982 and our "Grand Junction" analysis

Generic Licensed Site Layout

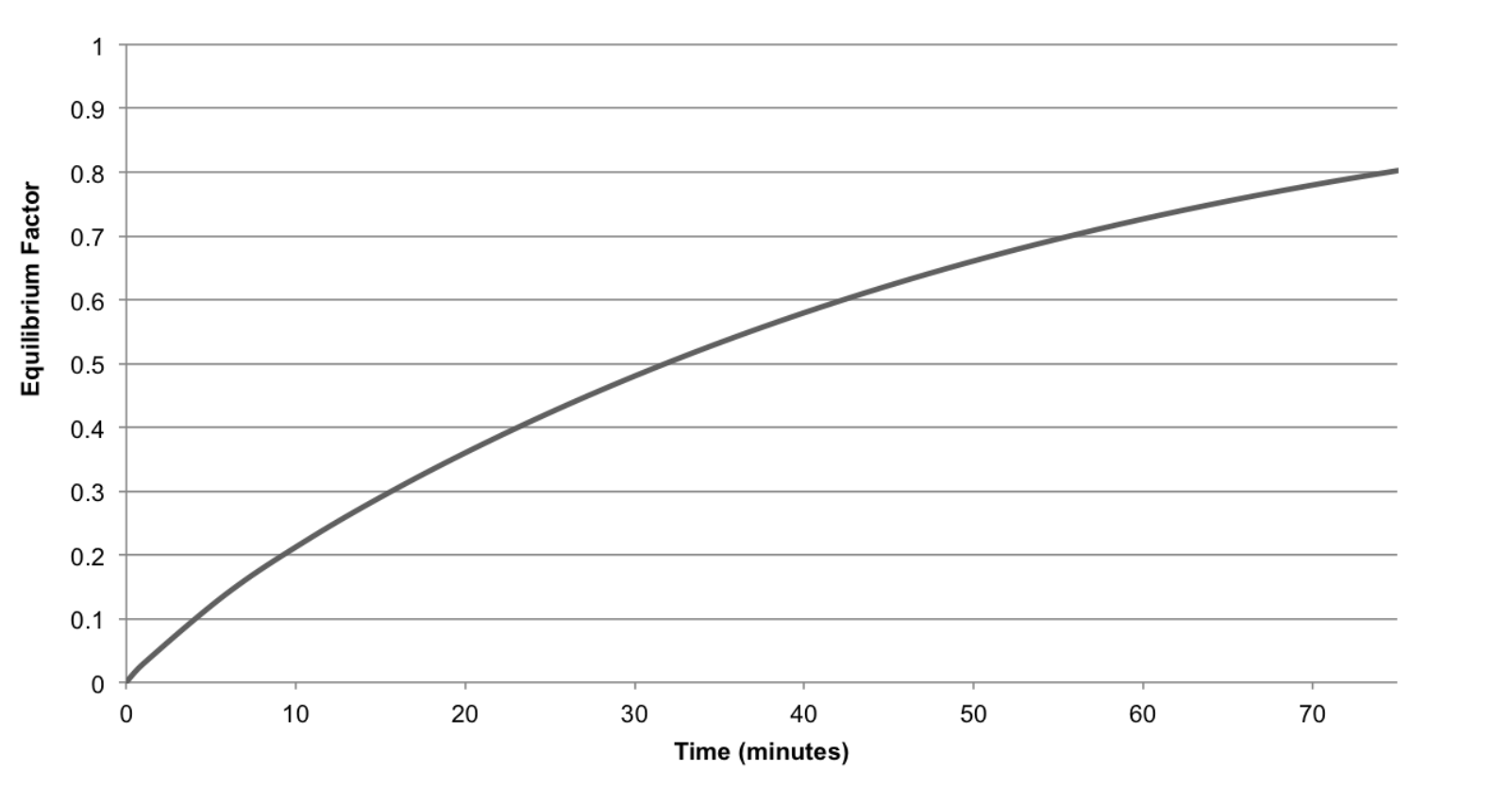


MILDOS- The Results:

Dose from 20 pCi/m^{2-} sec as (f) of Distance from Edge of Tailings

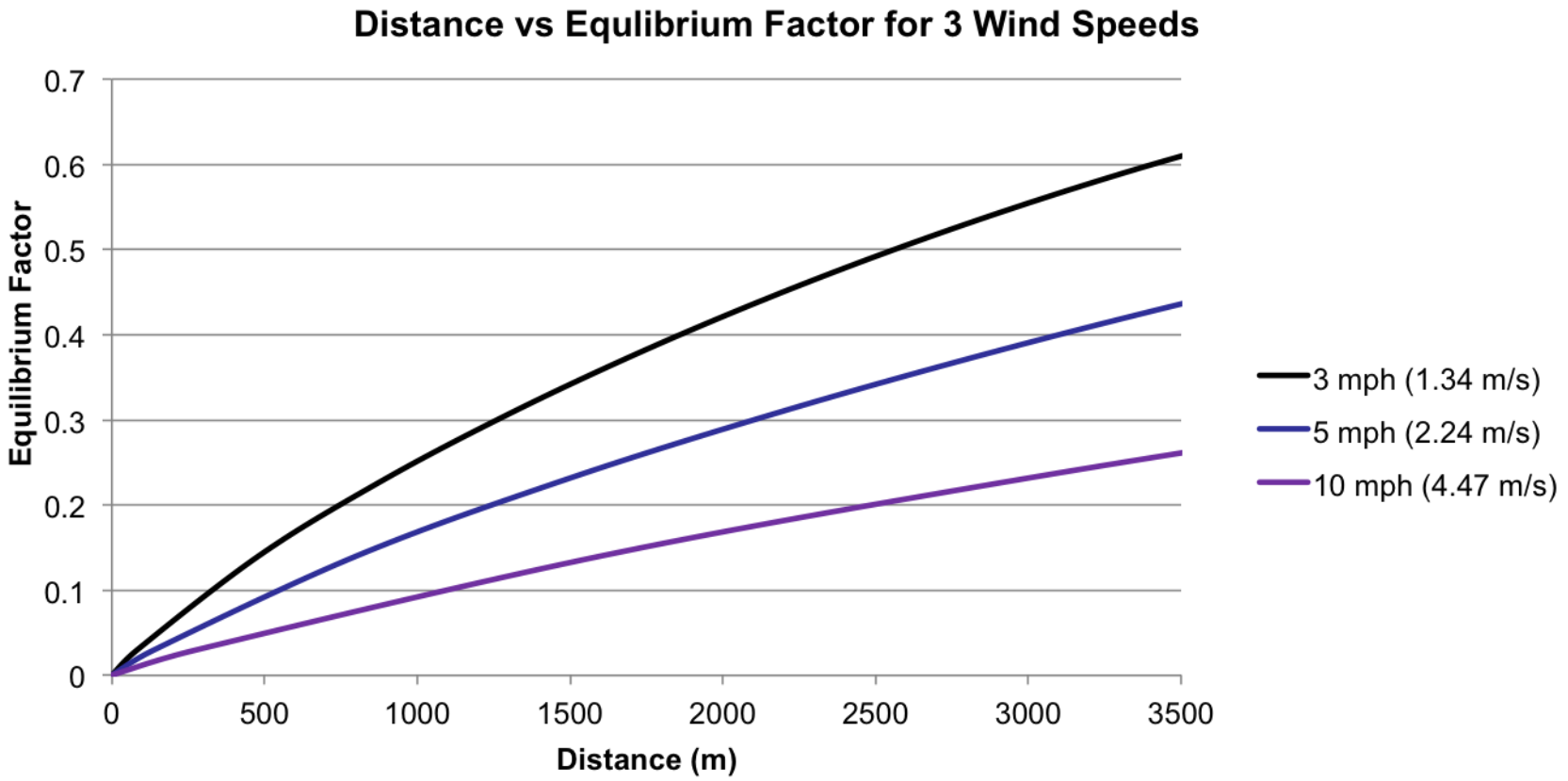


But Dose is from the Daughters - Radon Progeny Ingrowth



Source: After Evans, RD. *Engineers Guide to the Elementary Behavior Of Radon Daughters.Health* Physics,Vol 177, pp229-252.1969

Equilibrium Factor as Function of Distance ("Pure" Rn @ T & D = 0)



NRC and EPA Requirements Similar BUT:

PARAMETER	NRC (10CFR40, App A)	EPA (40CFR61,192)
Rn Flux Limit	20 pCi / m^2-sec	Same as NRC
Measurement	Method 115; only to demonstrate compliant closure	During ops pre 1989; same as NRC post closure (final radon barrier)
Public Protection via	air conc. and dose in unrestricted areas	flux (source term)
Final Barrier Emplacement	Can be phased using interim cover	Same as NRC
Acreage Exposed	No limitation	10 for continuous; 2 X 40 for phased

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Radon and ISRs

- **Two mechanisms of release:**
  - Dynamic release of Rn dissolved in lixiviant when initially exposed to atmospheric pressure (small leaks in well fields, header houses, IX - elution interface, surge ponds, restoration)
  - From decay of Ra 226 dissolved in water
- **Since sources are many and diffuse, cannot measure directly (e.g., isokinetically)**
- **Historical approach for demonstrating compliance to 10CFR40.65 effluent reporting,10 CFR 20 APP B and public dose limits is via calculations and results of environmental monitoring**

Radon , ISRs and 40 CFR 61 Subpart W

- **Accordingly, application of Sub W Rn emission limit and/or work practices should not be necessary for ISRs since:**
  - Adequate public protection and standards of care are provided under the AEA (e.g., 10 CFR 20.1301 and APP B; 10 CFR 40 App A)
  - Operating experience consistently demonstrates unrestricted area concentrations and public dose limits achieved and ALARA

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Physics is Interesting
- So What - Implications for Compliance and Measurement

- 10 CFR 20, Appendix B, Table 2 unrestricted area release limit * for Radon: 0.1 pCi/l ("with daughters present") vs. 10 pCi/l ("with daughters removed")
- Assignment of equilibrium factor has 2 orders of magnitude impact on applicable limit
- Can't "measure" 0.1 relative to BKG of 0.3++
- Can probably can measure > 1 above BKG

* *Annual average concentration – not a "ceiling" value*

Conclusions From All Of This:
What Does the Physics Teach Us ?

- Outdoor radon concentrations can vary considerably (diurnal, seasonal) by several pCi/l
- Due to this bkg variability, difficult to measure below about 1-2 pCi/liter incremental
- Release of radon from water ponds is small
- Source Term is “fresh radon” – only a fraction of progeny equilibrium within a mile of the source (dose is from the progeny)
- Accordingly, applicable 10 CFR 20 App B concentration limit in unrestricted areas (public) should be closer to10 pCi/liter (“w/o daughters present”) than 0.1 (“with daughters present”)

Conclusions From All Of This:
What Does the Physics Teach Us ? …cont'd

- Technical basis for 20 pCi/m2- sec limit as determined by EPA > 40 yrs ago and recent corroboration reported here demonstrates essentially BKG radon "off the pile" - even at the edge of the pile
- Constraint on source term in middle of licensed facility provides no additional public protection since (1) public has no access and (2) 10CFR20 and APP B already defines public exposure limit at points of compliance which are protective and already ALARA

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QUESTIONS ?