Radon

Exposures – Risks - Regulation

A Journey Through Time

Presented To:

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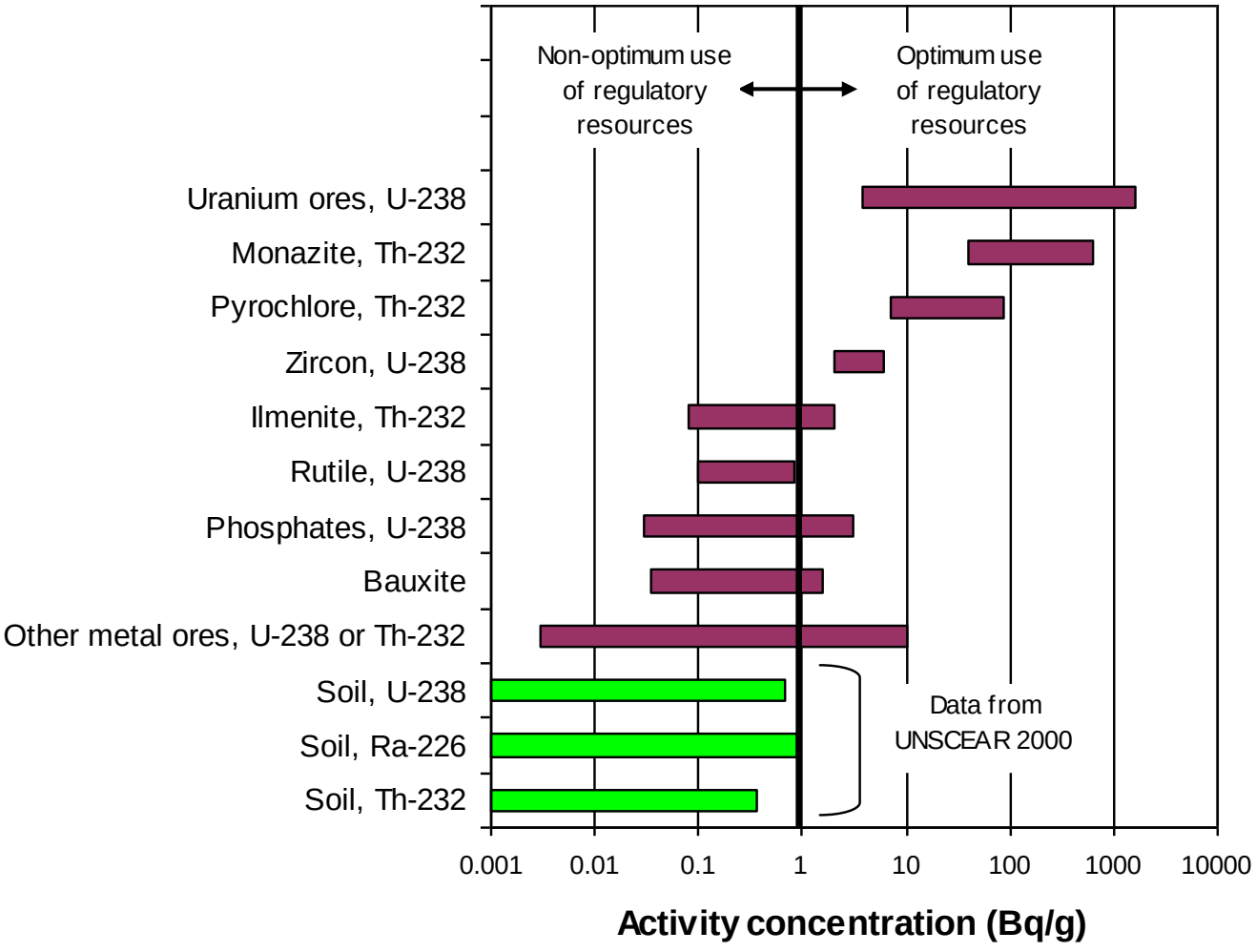
Everything is Naturally Radioactive

Uranium-238, Radium-226 and Radon-222 are Ubiquitous

Examples of NORM Sources

- All soils and rocks
- Uranium mining
- Rare earth minerals production
- Phosphate fertilizer production
- Tantalum and niobium raw materials
- Coal ash
- Copper mining wastes
- Etc.…

Radioactivity in Soils and Minerals



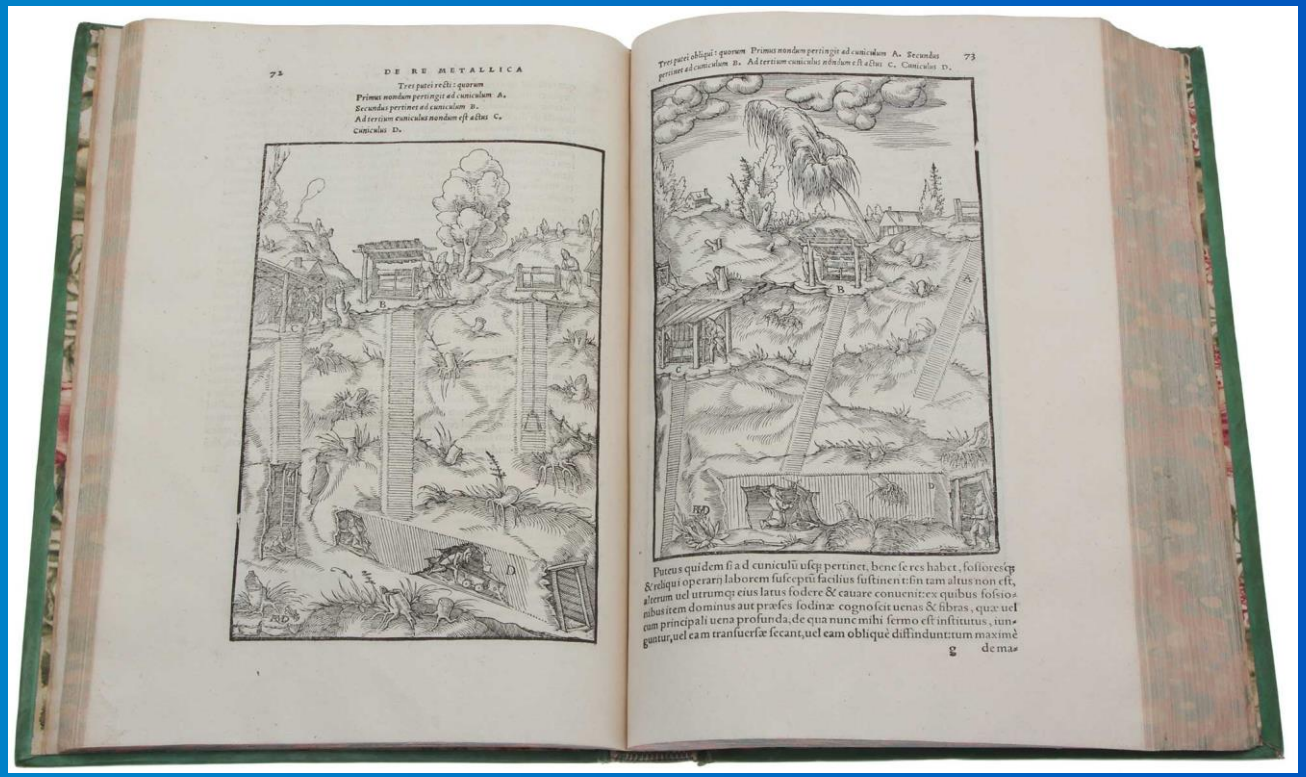
After Wymer, NORM V, 2008

Radon

- **A natural radioactive noble gas found everywhere**
- **Radon levels are higher indoors than outdoors):**
  - Average indoor level in US is about 1.3 pCi/L;
  - Average outdoor level in the US is about 0.4 pCi/L.
- **Ambient radon levels vary widely.**

Lung Disease in the Middle Ages

- In the 15th century, a large silver deposit was discovered at Joachimsthal in Bohemia which was the basis for Agricola's treatise on mining *De Re Metallica.*



Lung Disease and Radon in Miners

- This unusual lung disease was eventually, some 500 years later, recognized as lung cancer.
- This lung disease was reported to have caused up to 70% of the miners' deaths.
- Radon levels in these medieval mines were thought to have had radon progeny levels ranging from 30 to 150 WL.

Motivation for Occupational Radon Guidance

- Around 1950, Radon in US uranium mines was found to be of the same order as for mines in the Erz Mountains.
- In 1949, the U.S. Public Health Service became concerned about the potential hazard based on the experience of the Joachimsthal/Schneeberg mines.

Radon Concentrations Found in US Uranium Mines in 1949 to 1950*

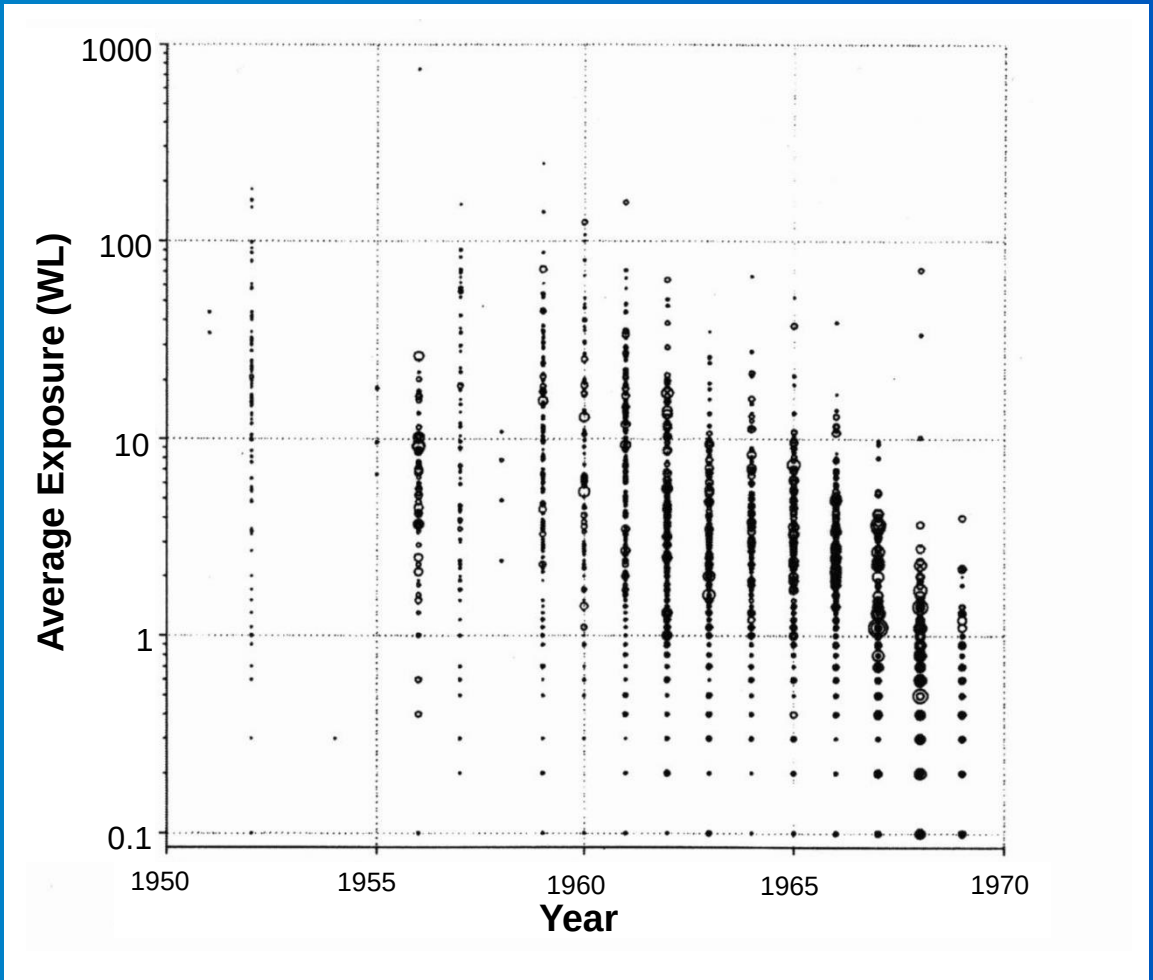
Area	# of Mines	Range of Radon Concentrations (pCi L^{-1})	Median Value (pCi L^{-1})
Navajo reservation	4	37 – 7,500	345
Utah	10	100 – 50,000	5,000
Colorado	24	135 – 22,300	2,540

* Holaday and Doyle, 1964

Motivation for Occupational Radon Guidance (Cont'd)

- **By the mid 1950's, there was a global awareness of the risk of lung cancer in miners**
  - This drove the development of radiation protection guidelines for radon and
  - consequent parallel changes to mining methods and ventilation practices which greatly reduced levels in mines

Measured Exposures for Underground Uranium Mines in Colorado



Evolution of Radon Standard in the USA -1

- The United States uranium industry began after World War II when the government began to buy uranium.
- Many miners worked in vanadium mines – the same ore basically as for uranium.
- Early mine operators knew nothing of the hazard of exposure to radon and no government agency had the authority to regulate the health and safety of miners.

Evolution of Radon Standard in the USA - 2

- **Beginning in 1954, the U.S. Atomic Energy Commission had regulatory authority over the uranium industry**
  - **After the material was mined** but had no authority to regulate the mining industry.
  - There were no mining industry standards and no personnel experienced in assessing the hazard within the mining community.
- **In 1955, the Public Health Service developed the concept of expressing a tolerance level in terms of the potential alpha energy of radon decay products in air**
- **In 1958, the Nuclear Standards Board of the American National Standards Association (later Institute), established a committee to develop a standard for uranium mines and mills.**

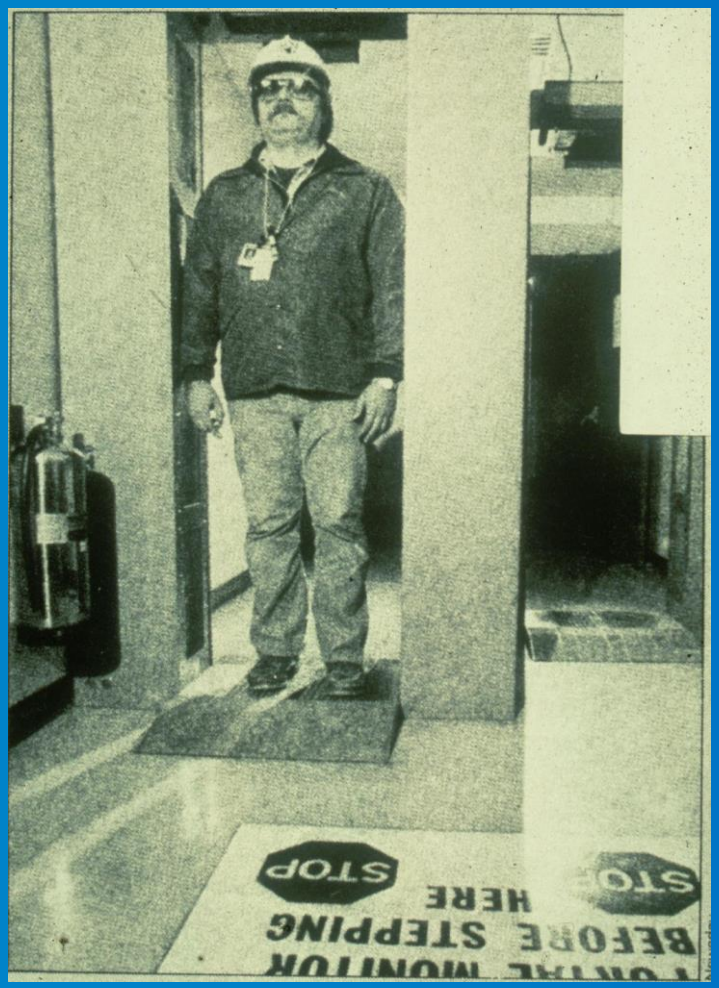
Evolution of Radon Standard in the USA - 3

- **A 1 WL standard was adopted in 1960 (12 working level months per year)**
  - It was thought to be directly related to lung dose.
  - The standard was the impetus for a significant decrease in miner exposures beginning in 1960, as states and mining companies began implementing control through mine planning and increased ventilation.
- **1967 Joint Committee on Atomic Energy**
- **The 4 WLM per year was adopted in 1971 and is still in effect in mines in the United States.**
  - ANSI is working on an update to N13.8-1973

Indoor Radon

- Interest in indoor radon got a boost in 1971 as a consequenceof elevated radon levels indoors in Grand Junction
- From 1951 to 1971 a uranium mill produced tailings that resemled clean sand that was used in fill under and around some 3000 houses were identified as contaminated with elevated radon levels
- Joint Committee on Atomic Energy 1971 looked at use of uranium mill tailings for construction drove interest in indoor radon

The “Initiating” Radon Event for the EPA



Stanley Watras at the Limerick Nuclear Power Plant, Christmas 1984

"I just thank God that if it was going to be anybody living in that house, it would be me, somebody who could, through their work activities, discover the situation,”

Philadelphia Inquirer March 20, 1985

EPA

- EPA was created in Dec 1970
- Over time, EPA developed a comprehensive Radon Action program including guidance on indoor radon, citizens guide to radon reduction and more
- EPA also developed NESHAPs guidance some of which is discussed later in following slides

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**

Subpart W
NESHAP for Radon Emissions from Operating Mill Tailings

- ***Affected Sources (Section A at p25397)***

  Include conventional impoundments and non-conventional impoundments where tailings are contained in ponds and covered by liquids – e.g., evaporation ponds …

  But

- ***Go on to comment (at p25398)***

  Because of the low potential for radon emissions from these impoundments, we do not believe it is necessary to monitor them for radon emissions... is difficult to determine whether there is any contribution above background values

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

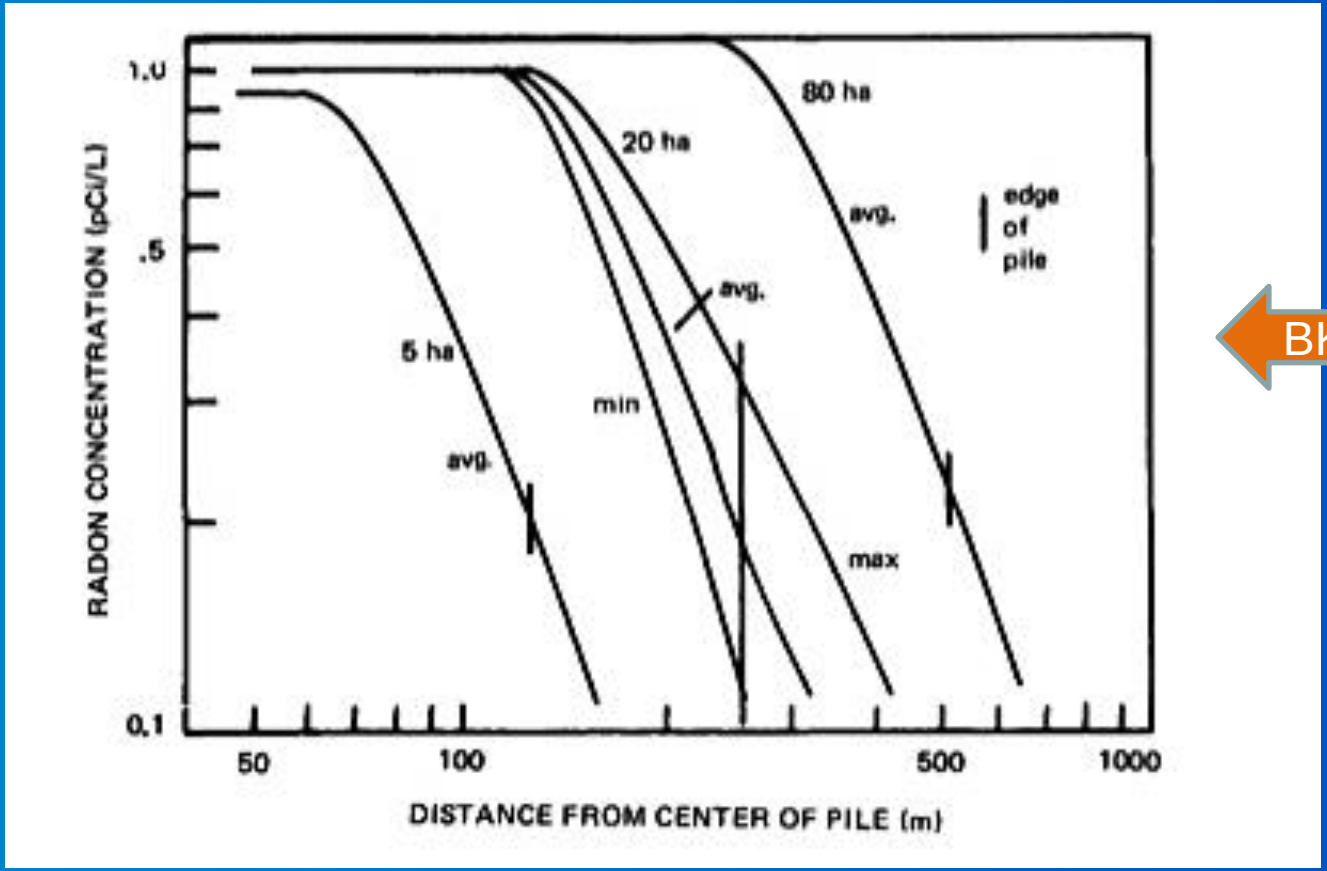
- US EPA 1982. *Final EIS for Remedial Action Standards for Inactive U Processing Sites*; EPA 520/4-82 013-1

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**

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

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

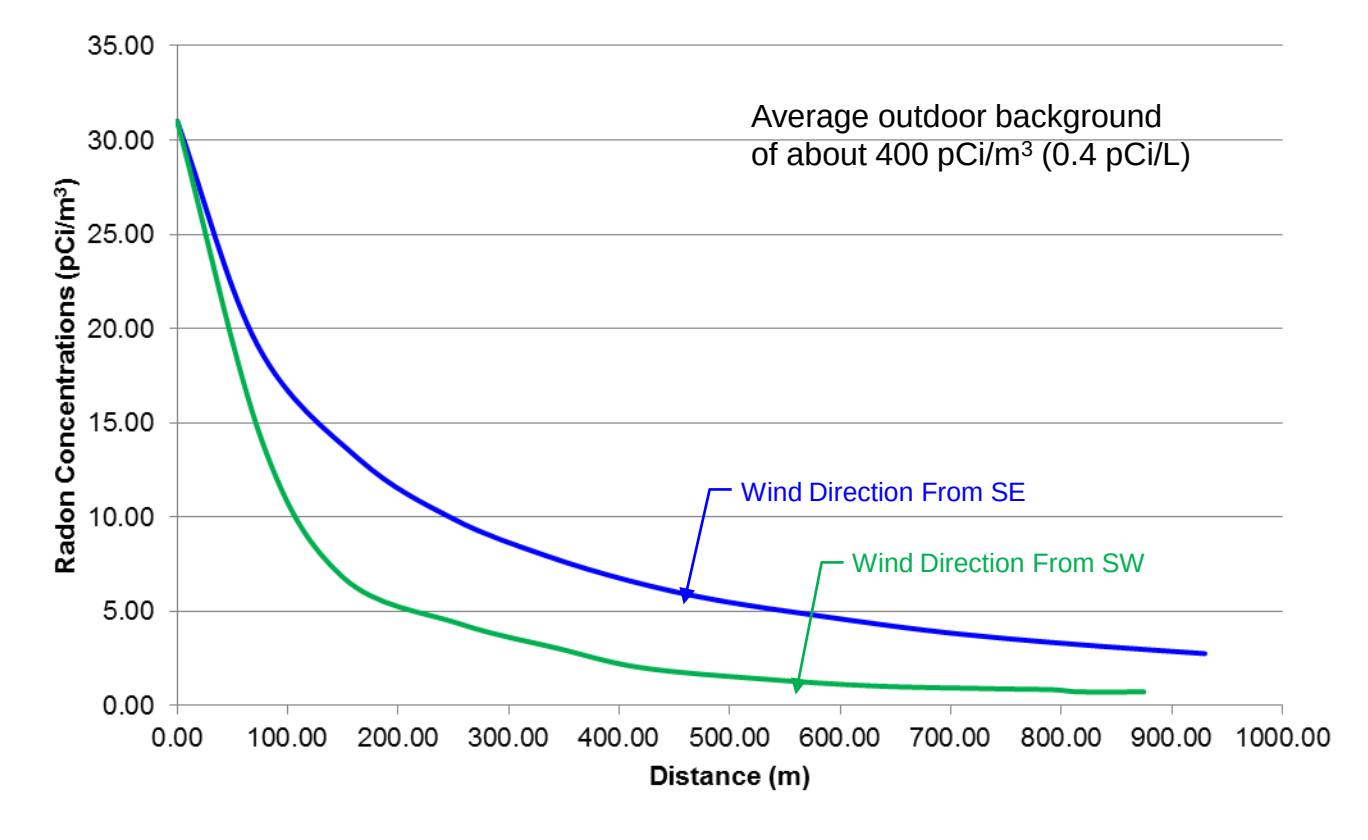
Physics is Interesting - So What - Implications for Compliance and Measurement

- 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
- Feq must be calculated, via travel time and ingrowth from “Fresh” radon

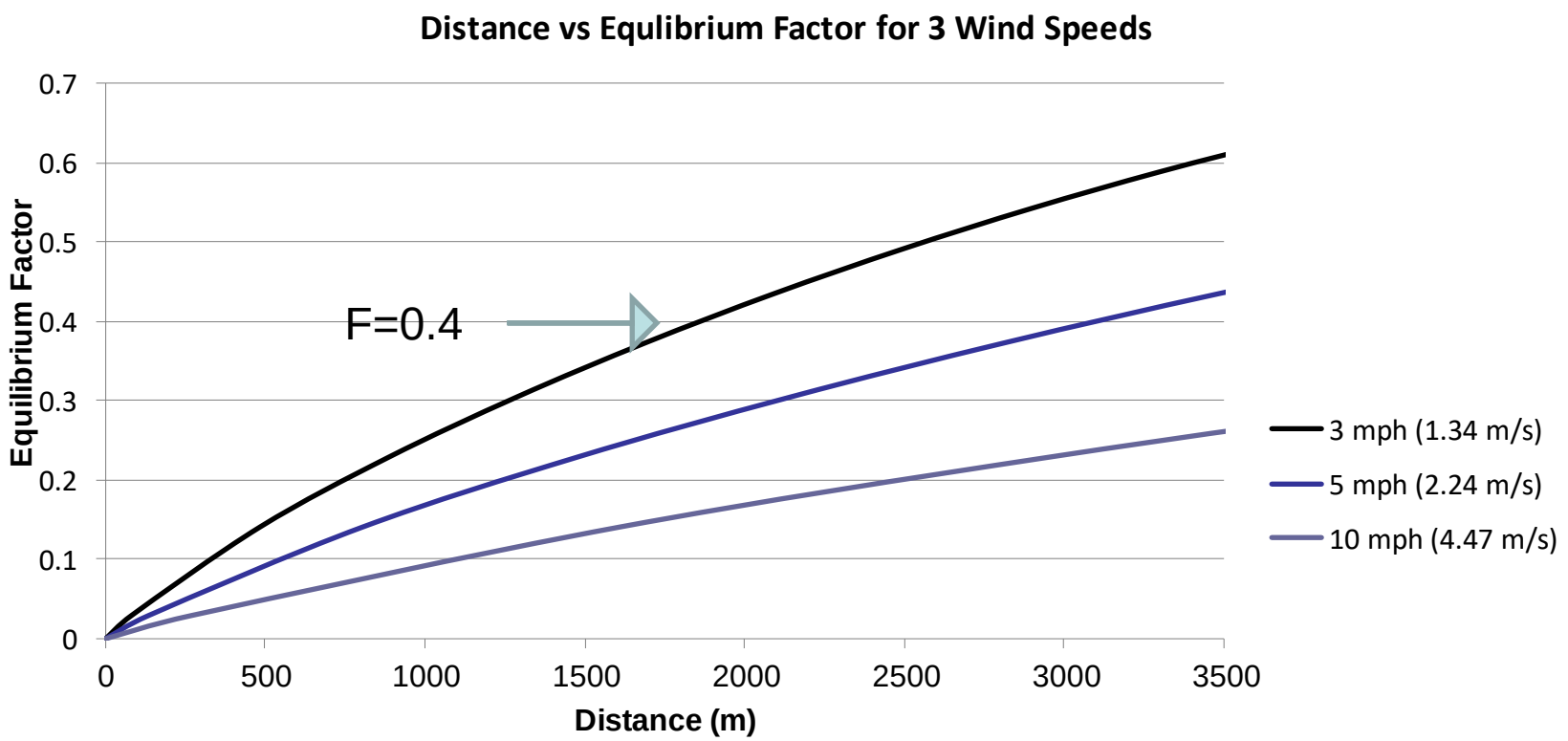
*** Annual average concentration – not a “ceiling” value**

Radon Concentrations from 40 Acre Tailings Cell

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

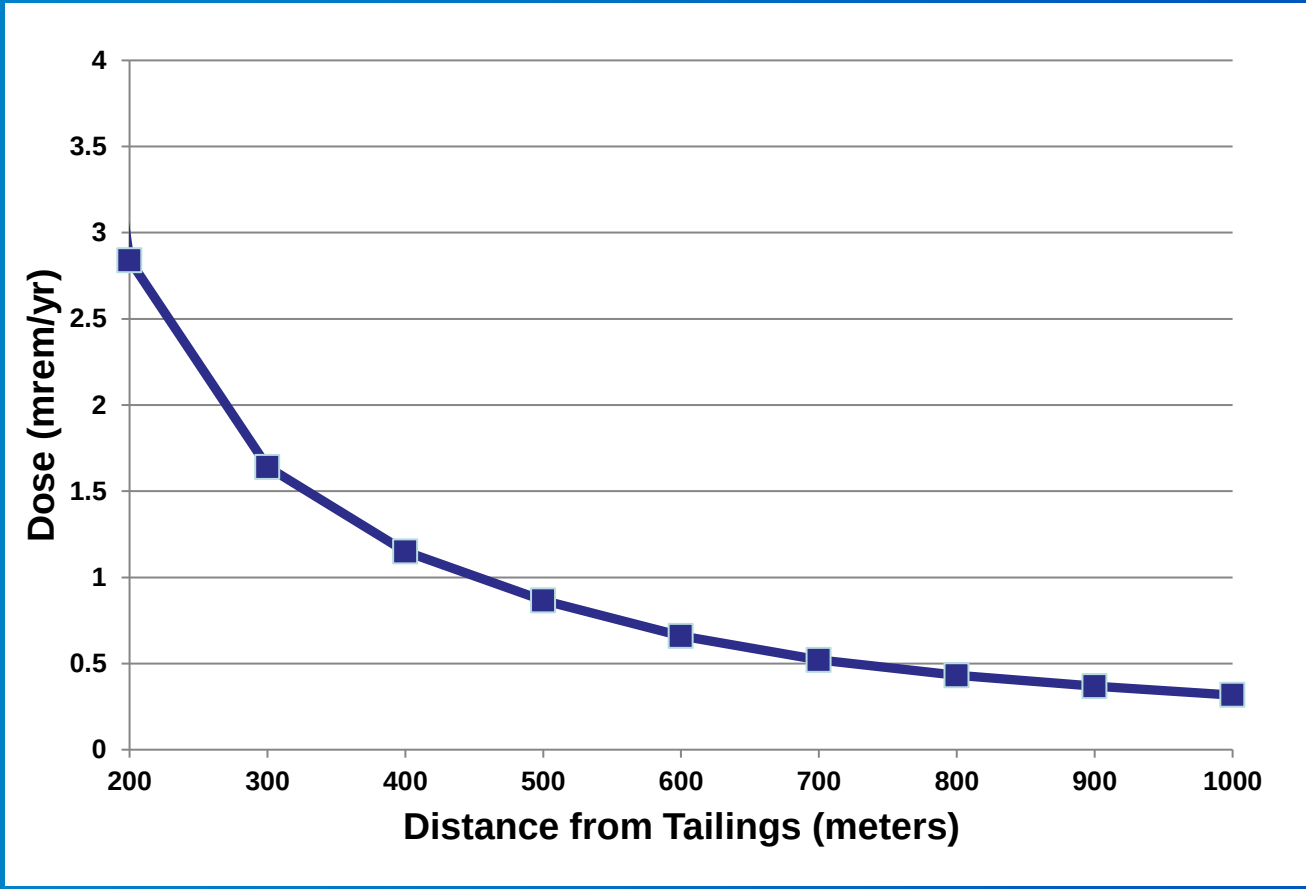


Equilibrium Factor as Function of Distance ("Pure" Rn @ T & D = 0)



MILDOS- The Results:

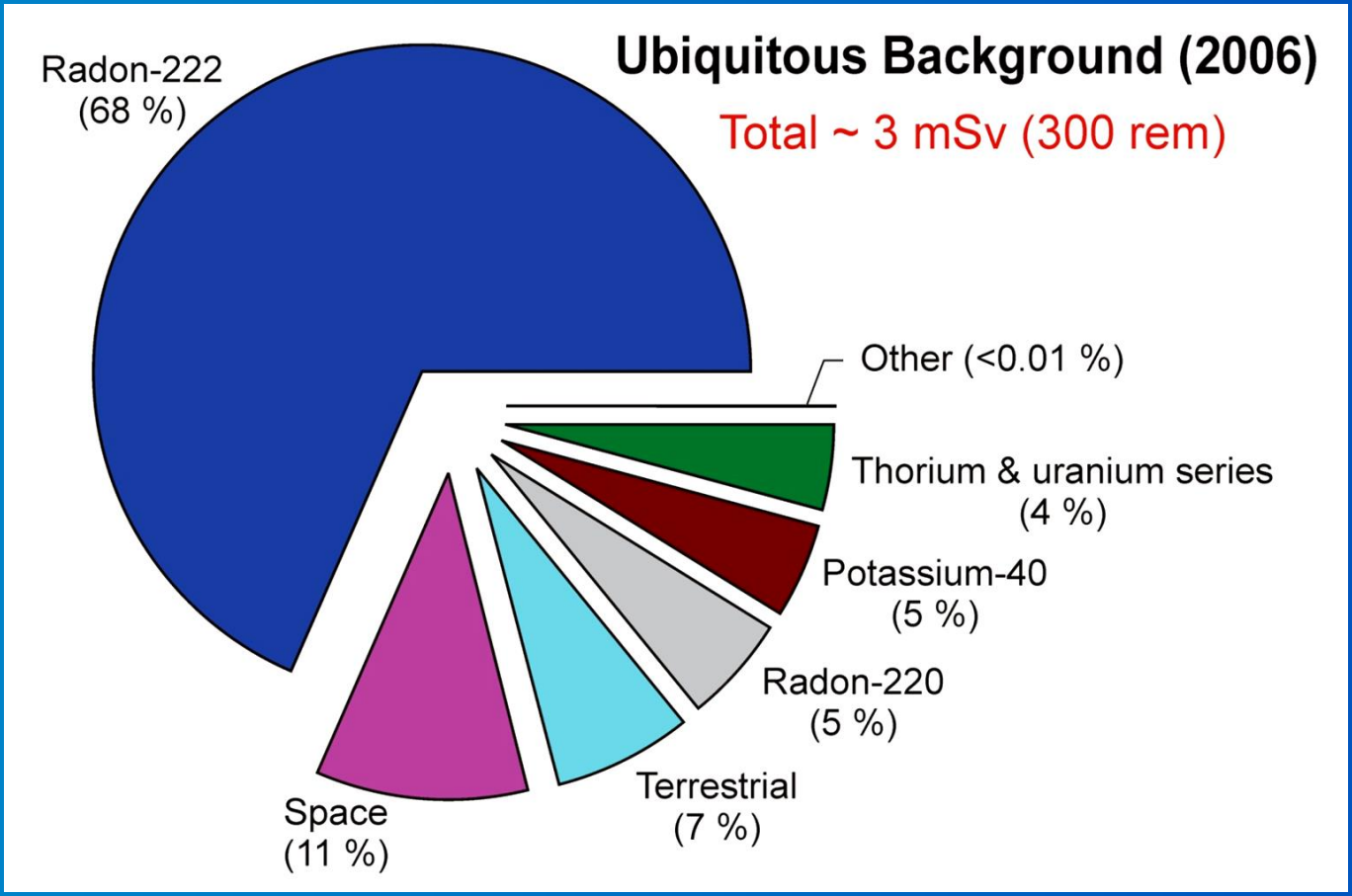
Dose from 20 pCi/m^{2}- sec as function of Distance from Edge of Tailings



Environmental Radon

- **EPA and NESHAPs (e.g., Subpart B)**
- **NRC and Mill Tailings**
- **Doses of the order of 10 mrem keep appearing in EPA and NRC guidance documents**
- **10 mrem is a very small dose**
  - A small fraction of natural background
  - Can't measure
  - Doses need to be estimated
  - Risks from a dose of the order of 10 mrem are also small

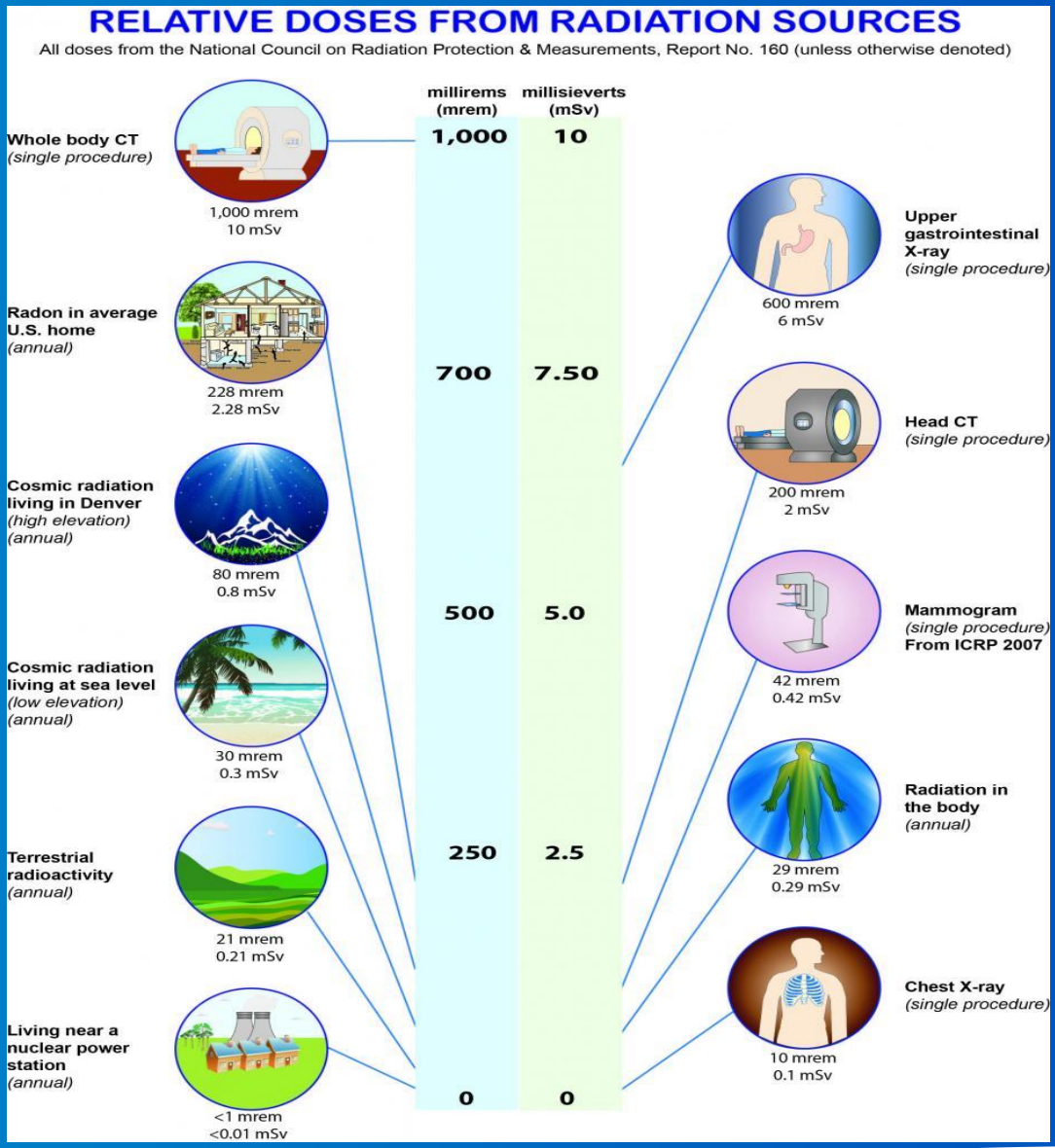
Sources of Radiation Exposure to the U.S. Population



Source: NCRP Report No. 160, 2009

https://www.epa.gov/radiation/calculate-your-radiation-dose

Doses from Common Radiation Sources



https://www.epa.gov/radiation/radiation-sources-and-doses

Risk from radon - smokers

RADON RISK IF YOU SMOKE

Radon Level	If 1,000 people who smoked were exposed to this level over a lifetime*...	The risk of cancer from radon exposure compares to**...	WHAT TO DO: Stop Smoking and...
20 pCi/L	About 260 people could get lung cancer	250 times the risk of drowning	Fix your home
10 pCi/L	About 150 people could get lung cancer	200 times the risk of dying in a home fire	Fix your home
8 pCi/L	About 120 people could get lung cancer	30 times the risk of dying in a fall	Fix your home
4 pCi/L	About 62 people could get lung cancer	5 times the risk of dying in a car crash	Fix your home
2 pCi/L	About 32 people could get lung cancer	6 times the risk of dying from poison	Consider fixing between 2 and 4 pCi/L
1.3 pCi/L	About 20 people could get lung cancer	(Average indoor radon level)	(Reducing radon levels below 2 pCi/L is difficult)
0.4 pCi/L		(Average outdoor radon level)	

Note: If you are a former smoker, your risk may be lower.

Citizens Guide to Radon: EPA402/K-12/002|2016|www.epa.gov/radon

Risk from radon – never smokers

RADON RISK IF YOU'VE NEVER SMOKED

Radon Level	If 1,000 people who never smoked were exposed to this level over a lifetime*...	The risk of cancer from radon exposure compares to**...	WHAT TO DO:
20 pCi/L	About 36 people could get lung cancer	◂ 35 times the risk of drowning	Fix your home
10 pCi/L	About 18 people could get lung cancer	◂ 20 times the risk of dying in a home fire	Fix your home
8 pCi/L	About 15 people could get lung cancer	◂ 4 times the risk of dying in a fall	Fix your home
4 pCi/L	About 7 people could get lung cancer	◂ The risk of dying in a car crash	Fix your home
2 pCi/L	About 4 people could get lung cancer	◂ The risk of dying from poison	Consider fixing between 2 and 4 pCi/L
1.3 pCi/L	About 2 people could get lung cancer	(Average indoor radon level)	(Reducing radon levels below 2 pCi/L is difficult)
0.4 pCi/L		(Average outdoor radon level)	

Note: If you are a former smoker, your risk may be higher.
*Lifetime risk of lung cancer deaths from *EPA Assessment of Risks from Radon in Homes* (EPA 402-R-03-003).
**Comparison data calculated using the Centers for Disease Control and Prevention's 1999-2001 National Center for Injury Prevention and Control Reports.

Citizens Guide to Radon: EPA402/K-12/002|2016|www.epa.gov/radon

EPAs dose calculator

- Look at variations in natural background dose across US
- https://www.epa.gov/radiation/calculate-your-radiation-dose

Relevant Uranium Recovery Issues for Radon

- **While 10 CFR Part 20 Dose Standards and EPA NESHAPs Regulations Are Well-Understood, No Uniform Guidance and Project Manager Application of:**
  - **Radon Source Identification;**
  - **Dose Calculation;**
  - **Individuals to Be Measured;**
  - **Regulatory Definitions**

Statutory/Regulatory Issue

- **Under the AEA, NRC is Not Permitted to Promote the Use of AEA Materials and Facilities;**

- **<u>Based on This, the Age-Old Adage Has Evolved to "You Propose, We Dispose:"</u>**

  - **Grant an Application As Submitted;**
  - **Grant With Conditions (Most Likely);**
  - **Deny**

Statutory/Regulatory Issue

- **The AEA's Application Process Mandate Begs the Following Question: What is a Project Manager's Role in Reviewing An Application?:**
  - **NRC Operates Under a Series of Regulations, Including But Not Limited to, Dose Assessments and Monitoring Plans;**
  - **Guidance Exists to Provide Applicants With a Pathway to Regulatory Compliance;**
  - **Without Both, The Applicant Proposes and a Project Manager's Responsibility is to Ask If the Proposal is Compliant; NOT TO REDEFINE REGULATIONS**

Uranium Milling and Radon

- **Conventional/Heap Leach Uranium Milling and ISR Are Different Animals:**

  - Conventional/Heap Leach Radon Sources Are easily Understood With or Without Guidance;
  - ISR Difficulties Are With Source Identification Without Guidance; Radon Monitoring Can Become Unduly Burdensome in the Face of Insignificant Risk;
  - Which Individuals Need to Be Assessed in Initial Applications and Renewals (i.e., Workers, Members of the Public, Maximum Potentially Exposed Non-Site Worker);
  - What is Appropriate Way to Calculate Dose Measurements

Further Complications

- **EPA Also Regulates Radon Emissions From "Tailings" Through 40 CFR Part 61, Subpart W:**
  - **What is the Legal Definition of Tailings?;**
  - **Why Have the Program in the First Place?;**
  - **Risk Versus Cost;**
  - **Why Not Rescind and Cede Authority to NRC Like Subpart T?**

Overriding Legal Issues

- **If NRC is Truly to Be Risk-Informed, One Must Look Only to Federal Case Law:**
  - **"Benzene" *AFL-CIO v. API* Case on OSHA Carcinogen Policy ("[B]efore he can promulgate any permanent health or safety standard…a threshold finding that a place of employment is unsafe—in the sense that significant risks are present….");**
  - **"Vinyl Chloride" NRDC v. EPA Case on Section 112 of the Clean Air Act: ("'safe' does not mean risk free…something is 'unsafe' only when it threatens humans with 'a significant risk of harm'";**
  - **Significant Risk Threshold Should Apply Equally to NRC as Mission of OSHA and EPA is Protection of Health and Safety**

Possible Solutions

- **NRC Has a Number of Solutions Available to It Given the Number of Uranium Milling Facilities in Agreement States:**
  - **(1): Workshop With Agreement States to Develop Uniform Radon Guidance;**
  - **(2): New ISR Rulemaking to Repeal Part 40.65 Rule and Rest on Part 20 and Guidance;**
  - **(3): SRP Revisions to Indicate that Satisfaction of Guidance Equates to Satisfaction of Regulation, Though Alternatives Are Allowed (Commission "Significant Weight" Case Law)**

Possible Solutions

- **Revise NUREG-1910 to Include "Model ISR Approach:"**
  - **NUREG-1910 is a Document Designed for Tiering and Not Necessarily for Codification of Radon Policies;**
  - **General Premises of ISR Sites by Region and Climate May Assist NRC Staff and Applicants in License Application Preparation;**
  - **Identify Satisfaction of Radon Policies Represents Satisfaction of Regulations;**
  - **Analogous to "Model Mill" in NUREG-0706 on Conventional Uranium Milling**