Performance Assessment in Support of Decision-Making

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Introduction

- Performance assessment (PA) with supporting "body of evidence" contributes to the safety case supporting decision-making
- Demonstrate with reasonable expectation that doses will be less than established standards, not predicting actual harm
- Administrative, engineered and natural safety functions contribute to safety and build confidence in protectiveness by providing layers of defense-in-depth

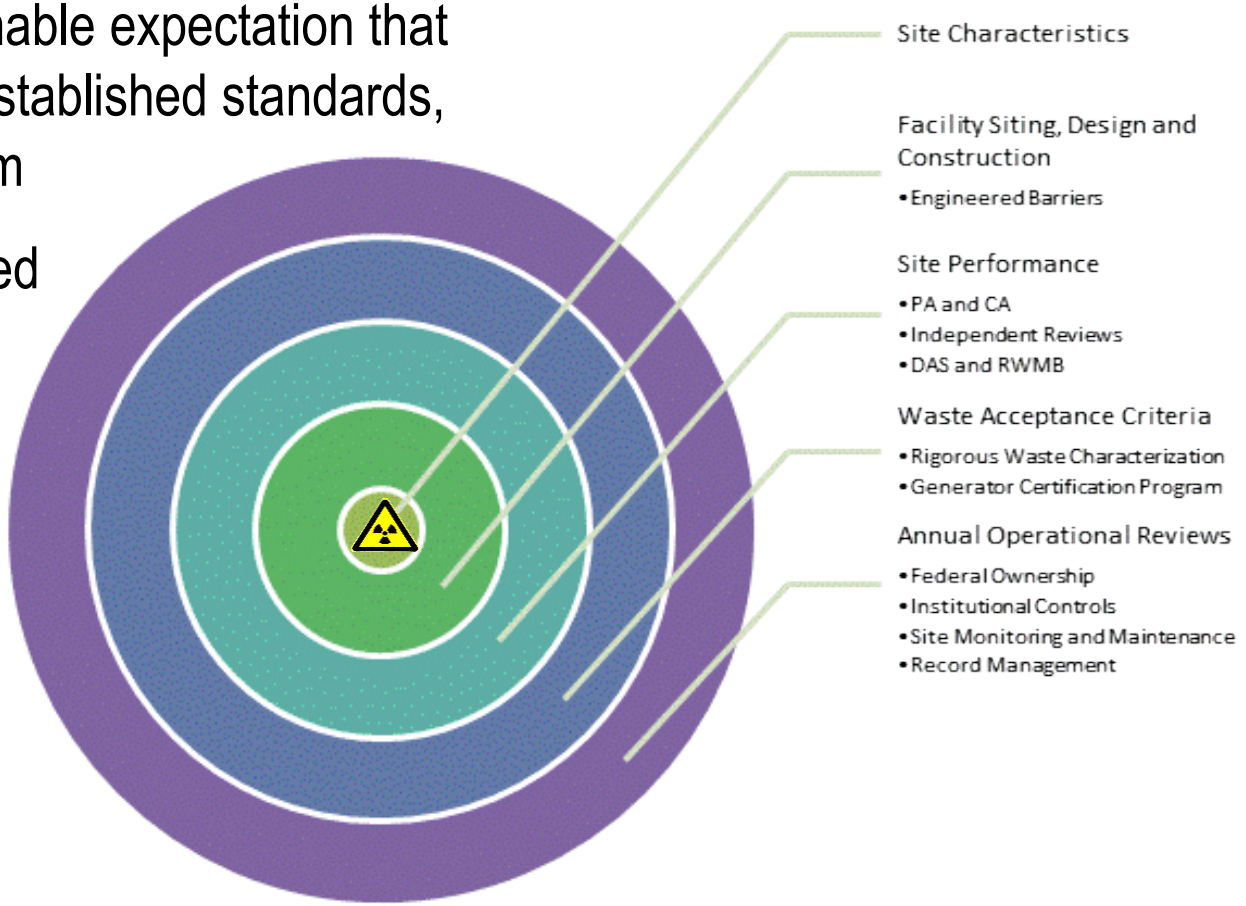


Figure: DOE presentation to NRC ACRS – October 2013

Content

- Discussion of factors contributing to safety (safety functions) and examples of defense-in-depth considerations
- Perspective on protectiveness of dose standards
- Examples of barriers and pessimistic assumptions
- Perspective on assumptions for hypothetical inadvertent intruder

Safety Functions - Examples

Features that contribute to safety for low-level waste (LLW) disposal include the following:

- Administrative
  - Public knowledge (societal memory, visitor centers, records)
  - Institutional controls (active: fences, guards; passive: deed restrictions)
  - Annual public dose limit – 100 mrem (LLW disposal four times less: 25 mrem)
  - Assumed receptors and habits (more highly exposed individuals)
- Engineered Barriers
  - Cover system, containers, waste forms, liner system
  - Physical and chemical barriers (water flow, contaminant transport)
- Natural Features of the Site
  - Low precipitation and infiltration rates
  - Thick vadose zone and aquifer (delay and disperse)

Safety Functions – Defense-in-Depth

- Administrative
  - Public knowledge (Societal Memory, Visitor Centers, Records)
  - Institutional controls (Active: fences, guards; Passive: deed restrictions)
  - Dose limits (4X less than public dose limit)
  - Assumed receptors and habits (most highly exposed individuals)
- Engineered Barriers (How do they change over time?)
  - Cover, containers, waste form, liner system
  - Physical and chemical barriers (water flow, contaminant transport)
- Natural Features of the Site
  - Low precipitation and infiltration rates
  - Thick vadose zone and aquifer (delay and disperse)

Memory and passive controls assumed to fail

Fraction of average annual dose

Subsistence farmer, Inadvertent Intruder

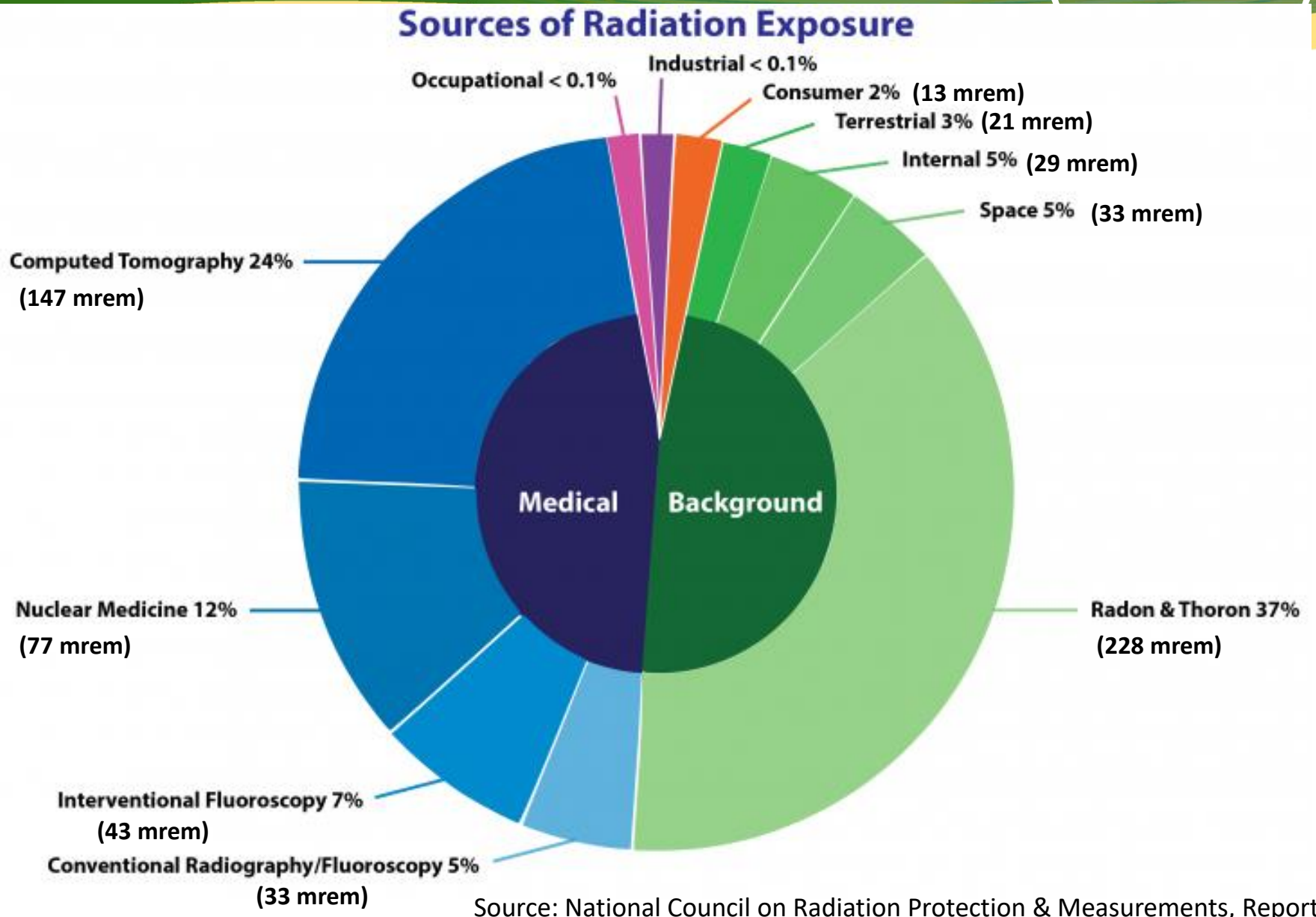
Consider early failure, Ignore some barriers,

Higher than expected infiltration through cover

Extreme infiltration cases (climate change, lack of vegetation)

Potential fast flow in vadose zone, less mixing in aquifer

Annual Average Dose in the United States (620 mrem)



Source: National Council on Radiation Protection & Measurements, Report No. 160

Relative Doses from Radiation Sources

400 mrem

350 mrem

300 mrem

250 mrem

200 mrem

150 mrem

100 mrem

50 mrem

0 mrem

Full-body CT scan (X-ray)
Average 5 to 10 rem per session

Average natural background dose to the U.S. population 310 mrem per year

DOE/NRC standard for the general public
100 mrem per year

Radon Average U.S. population
200 mrem per year (Average)
576 mrem per year (4 pCi/L in your home - EPA calculator)

Normal cosmic radiation at Hanford
28 mrem per year

DOE/NRC performance objectives for LLW disposal
25 mrem per year

Nuclear Medicine Procedure
50 mrem per year

One Mammogram
30 mrem

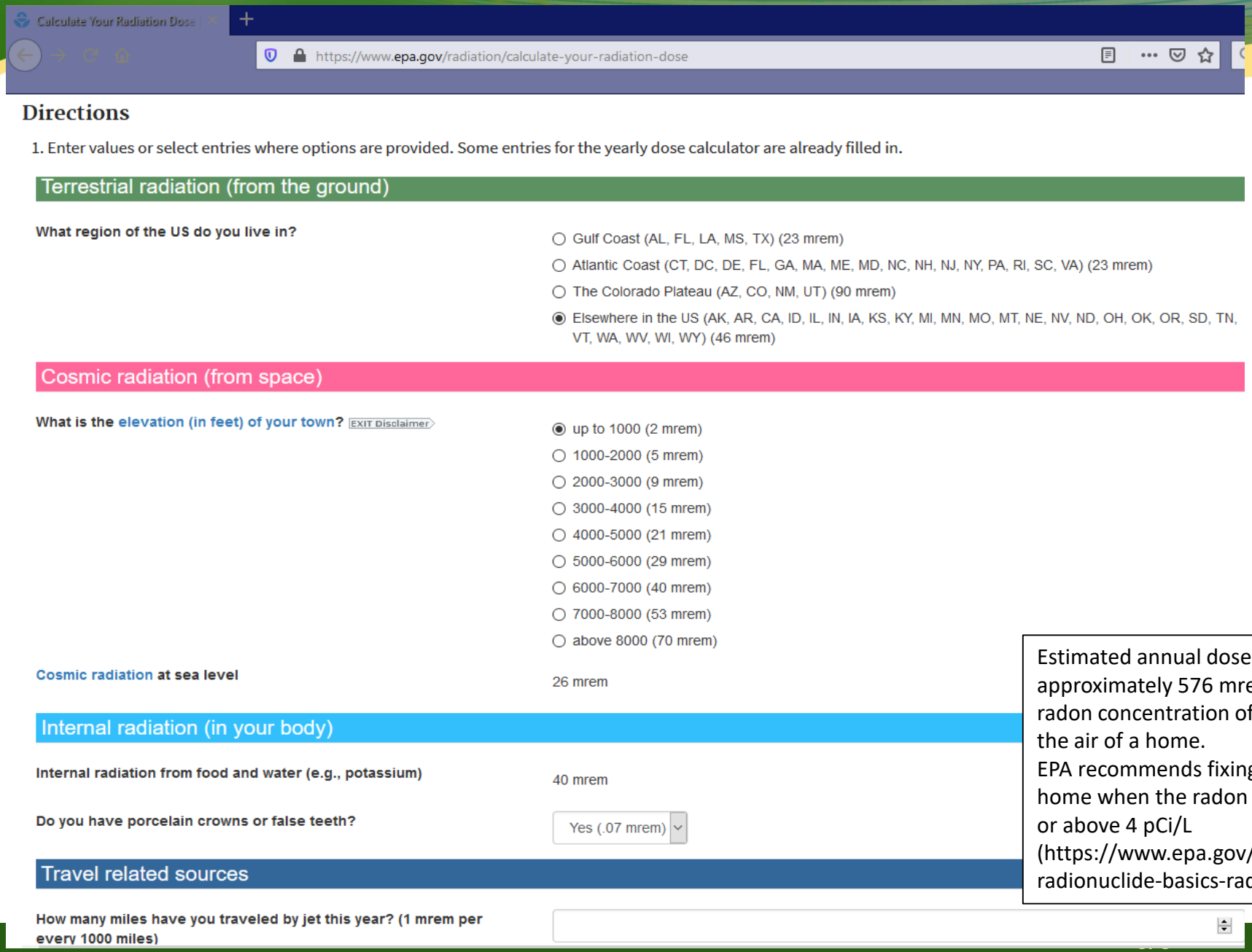
EPA dose standard for air emissions
10 mrem per year

Round-trip flight from Washington D.C. to Seattle
3.8 mrem

Smoke Detectors
Less than 0.001 mrem per yr

Sources: https://www.epa.gov/radiation/radiation-sources-and-doses
https://www.nrc.gov/about-nrc/radiation/around-us/calculator.html
Mettler Jr, Fred A., et al. "Effective doses in radiology and diagnostic nuclear medicine: a catalog." Radiology 248.1 (2008): 254-263.

EPA Radiation Dose Calculator (Partial Screenshot)



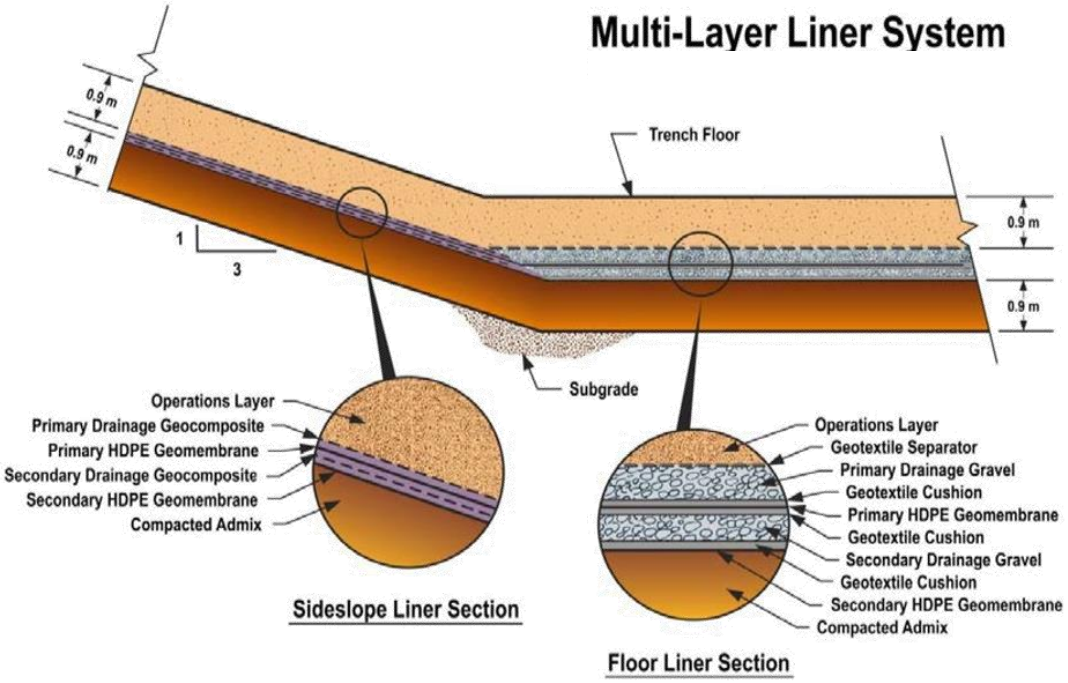
Estimated annual dose of approximately 576 mrem for a radon concentration of 4 pCi/L in the air of a home.
EPA recommends fixing your home when the radon level is at or above 4 pCi/L (https://www.epa.gov/radiation/radionuclide-basics-radon).

Barriers – Defense-in-Depth

- Barriers expected to perform for very long times (thousands of years). PA considers varied degrees of degraded performance for defense-in-depth.
- Pessimistic bias often considered for
  - Effective life of engineered barriers
  - Performance of barriers
- Multiplied through the PA
  - Waste Form
  - Containers
  - Cover System
  - Liner System

Stainless Steel Container

Multi-Layer Liner System



Inadvertent Intrusion – Defense-in-Depth

Sequence of events often assumed to occur for inadvertent intrusion scenario (How likely is each one and over what time?)

- Memory of Hanford Site is forgotten? (becomes more likely over time)
- DOE required institutional controls fail? (becomes more likely over time)
- Someone drills a well in the general area of a disposal facility? (local drilling density)
- Driller will climb steep slope of the cover rather than drilling alongside the cover?
- Well is drilled with in the footprint of disposed waste (or as an extreme, the exact location of a specific waste stream)? (local drilling density)
- Drill bit will go through container and waste form without driller noticing difference? (depends on container/waste form degradation and drilling method)
- Driller will not recognize that container and waste materials are not soil and stop to investigate (depends on when waste is indistinguishable from soil)
- Resident will mix container and waste cuttings in a garden (depends on when waste is indistinguishable from soil)
- Waste cuttings will behave like soil for resuspension and uptake into food chain

Key Points

- PA is not a prediction of the level of harm, it is a quantitative input for the safety case used to support decisions regarding reasonable expectation of *not exceeding* performance objectives
- Demonstrating "less than" leads to a process where pessimistic bias is built into many aspects of the analysis to provide defense-in-depth and build confidence in conclusions
- Many different safety functions contribute to protectiveness of a disposal facility (administrative, engineered and natural) – as you look at results, ask yourself what assumptions were made for the safety functions (ignored, pessimistic, expected)
- PAs often investigate cases where safety functions are assumed to not perform as expected, as part of building confidence for the decision to be made