Internal Dosimetry Challenges When Dealing With Transuranic Radionuclides

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Outline

- Transuranics, Source Material, and SNM
- Internal Dose Concepts
- Internal Dose Assessment
- Lessons Learned

Transuranics

- Transuranic (TRU) Elements are actinides with atomic numbers from 93 (neptunium) through 103 (lawrencium).
- Most have isotopes with half lives of the order of minutes or less and are not a substantial health concern.
- The nuclides of greater interest: Np-237, Pu-238, Pu-239, Pu-240, Am-241, and Cm-243/Cm-244
  - Long Half-Lives
  - Alpha Emitters

Source Material

- Uranium or thorium or any combination of uranium and thorium in any physical or chemical form but classified as-
- Ores that contain by weight, one-twentieth of 1 percent (0.05 percent) or more of uranium, thorium, or any combination of uranium or thorium
- Source material does not include SNM
- Naturally Occurring

A.W. Jolliffe, Dr. Russell and Frank Sentfle on a GSC field party exploring for uranium in the NWT in 1944 with the aid of an ionization chamber.
A.W. Jolliffe, Dr. Russell et Frank Sentfle, tous membre d'une équipe de terrain de la CGC, explorent pour de l'uranium au T.N.O. en 1944 à l'aide d'une chambre d'ionisation.
Photo: Alfred Walton Jolliffe Papers, Queen's University Archives

Special Nuclear Material (SNM)

- Plutonium
- Uranium-233 (enriched)
- Uranium-235 (enriched)
- Anything the NRC says is SNM that is not source material
- Most are Fissile

Internal and External Dose

- External Dose:
  - Radiation Source outside of body
- Internal Dose:
  - Radiation Sources within body

External Dose

- 3 Standard reference points
  - Shallow Dose: Live skin tissue at an average depth of .007 cm.
  - Deep Dose: Internal organs close to the body surface, 1 cm.
  - Eye Dose: Lens of the eye at a tissue depth of 0.3 cm.
- Shallow Dose Equivalent, SDE
  - Alpha radiation not a hazard
  - consider beta and gamma radiation.
- Deep Dose Equivalent, DDE
  - Alpha and Beta radiation not a hazard.
  - For gamma, SDE = DDE (typically)

Internal Dose

- All radiation types present a hazard
- 2 Dose quantities:
  - Committed Dose Equivalent, CDE (specific to a particular organ)
  - Committed Effective Dose Equivalent, CEDE
- CDE and CEDE calculated over 50 years following intake and assigned to year of intake

Internal Dose Concepts

- Intake: Quantity of nuclide that enters body.
- Uptake: Quantity of nuclide that gets initially deposited in body or a specific organ.
- Internal dose may be delivered over many years post intake.
- Uptakes are determined by knowing the intake and the biological model associated with the nuclide.

Committed Effective Dose Equivalent, CEDE

$$CEDE = \sum CDE * W_t$$

W_t is a tissue weighting factor. This represents the various sensitivities that each organ has to radiation.

Weighting Factors for Various Organs

Gonads	0.25
Breast	0.15
Red Bone Marrow	0.12
Lung	0.12
Thyroid	0.03
Bone Surfaces	0.03
Remainder	0.30
Whole Body	1.00

per 10CFR20

Annual Limit on Intake, ALI

- Listed in 10CFR20 for each Isotope for Inhalation or Ingestion
- Represents a Quantity of Radioactive Material, uCi.
- Results in Annual Dose Limit if Inhaled or Ingested For the Assumptions Used:
  - Particle Size
  - Breathing Rates
  - Metabolism of “Reference Man”
- 1 ALI = 5 rem CEDE or 50 rem CDE

10CFR20 Compliance Methods

- Intakes < 1 ALI per Year, or,
- DAC-HRS < 2000 if only inhalation,
- Using Bioassys or Air Samples:
  - CEDE < 5 rem, and
  - CDE < 50 rem for all organs

Intake Modes

- Inhalation
  - DACs/ALIs depend on: solubility, particle size
- Ingestion
  - Large “inhaled” particles result in swallowing intake
  - Quite common for complex “real-world” cases
- Bioassays may help deduce inhaled and ingested amounts

Bioassay Intake Assessment

- In-vivo bioassay
  - Whole body counting
  - Lung counting
- In-vitro bioassay
  - Urine Sampling
  - Fecal Sampling

•Integration of all methods allows for "estimates" of:

- •particle size
- •ingestion vs inhalation quantities
- •intakes and doses

•Professional Judgement Required

In-vivo Bioassay

- Good for “Easy to Measure” nuclides (i.e. gamma emitters)
- Some systems can resolve lung/gutt geometries
  - estimates intake pathway (i.e.inhalation or ingestion)
- Effectiveness Depends on Beta:Alpha Ratios !!!!!

In-vitro Bioassay

- Urine sampling
  - soluble nuclides
- Fecal Sampling
  - in-soluble nuclides
  - alpha emitters
- Time is of the essence in sampling
- Not a pleasant experience for the worker

Typical Causes of Internal Dose

- Work with Dispersible Sources
- Work in Contaminated Areas
- Work in Airborne Radioactivity Areas
- Dismantling Systems and Components
- Improper Ventilation
- Inadequate Protective Clothing
- Inadequate Respiratory Protection

Airborne Radioactivity Considerations

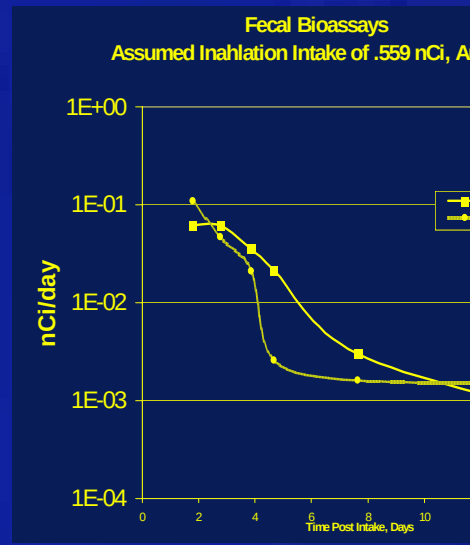
- Nuclide Ratios Can Be Inconsistent and Unpredictable
- Usually Instantaneous or Short Duration
- Chronic Occupied Particulate Airborne Levels are Rare

Alpha Contamination Hazards

- High “energy transfer”
  - High Quality Factor: 1 rad = 20 rem
  - “More dose equivalent for your dose”
  - Large Energy Deposition in a Short Track
  - Short Range - High Dose
- Not an External Hazard
- Large Internal Hazard

Alpha Contamination Challenges

- Small Amount Lead to Very High Internal Doses
  - 13,200,000 dpm Co-60 = 1 rem
  - 2,640 dpm Am-241 = 1 rem
- Difficult to Detect in People
  - WBC does not detect Alpha contamination
  - > 500 mrem Intakes Can be Missed by WBC Due to Low Beta / Alpha Ratios
- Detection Challenged by Radon
  - Relatively High
  - Changes with weather, time, location.

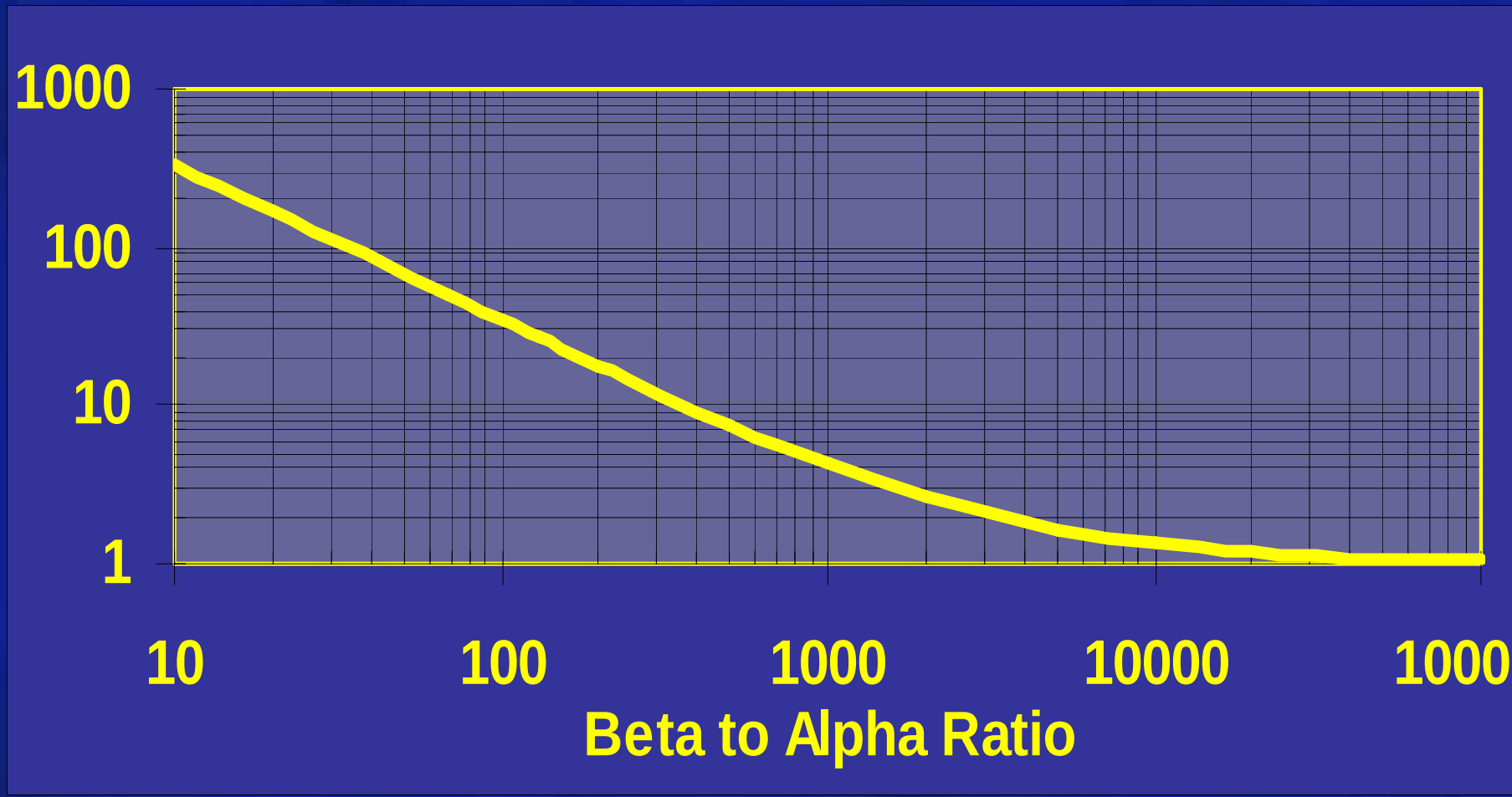


Comparison of Alpha Risks

Isotope	Half Life	Ingestion ALI, uCi	Inhalation ALI, uCi
Np-237	2,140,000 y	0.5	.004
Pu-238	88 y	0.9	.007
Pu-239	24,131 y	0.8	.006
Am-241	432 y	0.8	.006
Rn-222	3.8 d	None	10,000
Rn-222 with daughters	3.8 d	None	100
Co-60	5.26 y	200	30
Cs-137	30 y	100	200
Mn-54	313 d	2000	800

Beta/Alpha Ratio for Co-60 & Am-241 = 30 ÷ 0.006 = 5,000

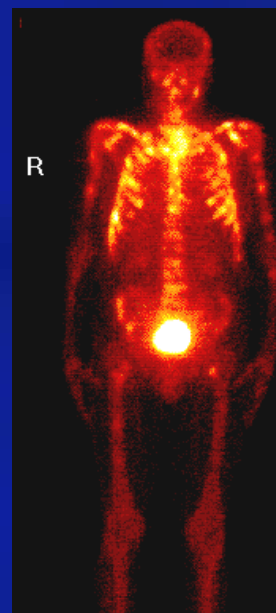
Relative Internal Dose Potential For Co-60 and Am-241 Versus Beta: Alpha Ratio



Lessons Learned to Safely Work with Transuranics

Implement an Effective Internal Dose Control and Monitoring Program

- Source Minimization and Personnel Protection
- Implementation Effective Monitoring for Transuranic Radionuclides
  - G/A Air Sampling
  - Lapel Air Sampling
- Establish Area Controls for Alpha Areas



Implement an Effective Internal Dose Control and Monitoring Program

- Establish a Consistent Process for Identification of Intakes
  - Air Sampling Action Levels
  - WBC Initiation Events and Action Levels
  - In-Vitro Sampling
    - Initiation for Urine and Fecal Sampling
    - Process Flow for Information Flow
  - Random Bioassay Selection
- Thorough Internal Dosimetry Assessment Process

Implement Internal Dose Protection Measures

- Minimize Sources and Perform Aggressive Decontamination of Alpha Radionuclides
- Use engineering controls
  - Ventilation
  - Water
- Protective Clothing
- Respirators

Perform Aggressive Internal Hazard Monitoring

- Contamination Levels
  - Ingestion hazard
  - May Be A Source for Airborne
  - Do Good Surveys!
- Airborne Radioactivity Levels
  - Inhalation hazard
  - Do Good Air sampling!
    - General Area
    - Personal

Understand Challenges of Alpha Airborne Monitoring

- Critical to assess intakes (or lack of)
- Radon Interference causes challenges
- Other monitoring concerns
  - Depth of burial
  - cross contamination

Understand Limitations of General Area Air Samples

- Used to assess peak values
- Used to determine posting requirements
- May not be representative enough for personnel intake assessment

Implement Personal (Lapel) Air Sampling

- Used as an Indicator for Potential Intakes
- True Breathing Zone Samplers
- Not good for measuring DAC for posting
- Great for measuring “INTAKE”
- Can be used as “INTAKE DOSIMETERS”

Lapel Air Sampler Intake Assessment

- Reference Man breaths 1200 lph (working)
- Lapel Air Sampler flow rate = 2 lpm = 120 lph
- Ratio of Reference Man to Lapel = 10:1
- The INTAKE of the worker = 10 * Lapel Activity

Benefits of Using Lapel Air Samplers

- More Representative than General Area Samples
- Excellent Sensitivity to Alpha Intakes
- Rapid Indication of Potential Intakes
  - Generally Conservative for Inhalation Intakes
- Easy to Use
  - No need to track on/off times
  - No need to calculate air volume
  - Just know who it belongs to and don’t lose it!
- Provides “Negative” Documentation
  - Worker and Public Trust

Implement a Process to Quickly Identify Potential Intakes

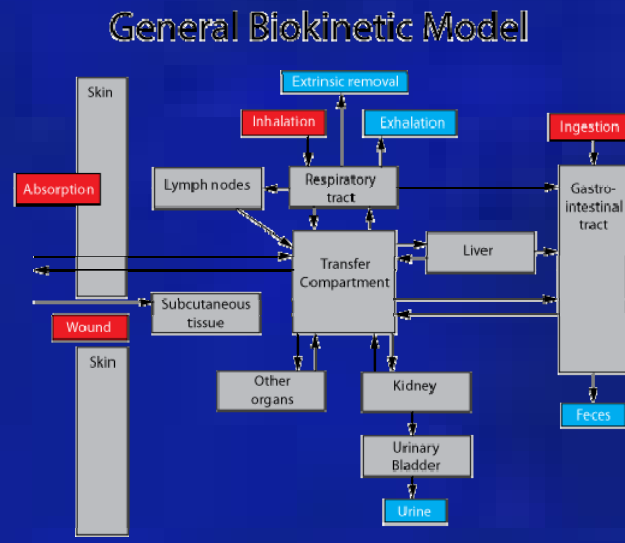
- Personnel Contaminations
  - Focus on Facial Area
- Positive Random WBC
- Unexpected Positive General Area Air Samples
- CAM Alarms
- Positive Lapel Air Sample Results

Establish Area Controls for "Alpha Areas"

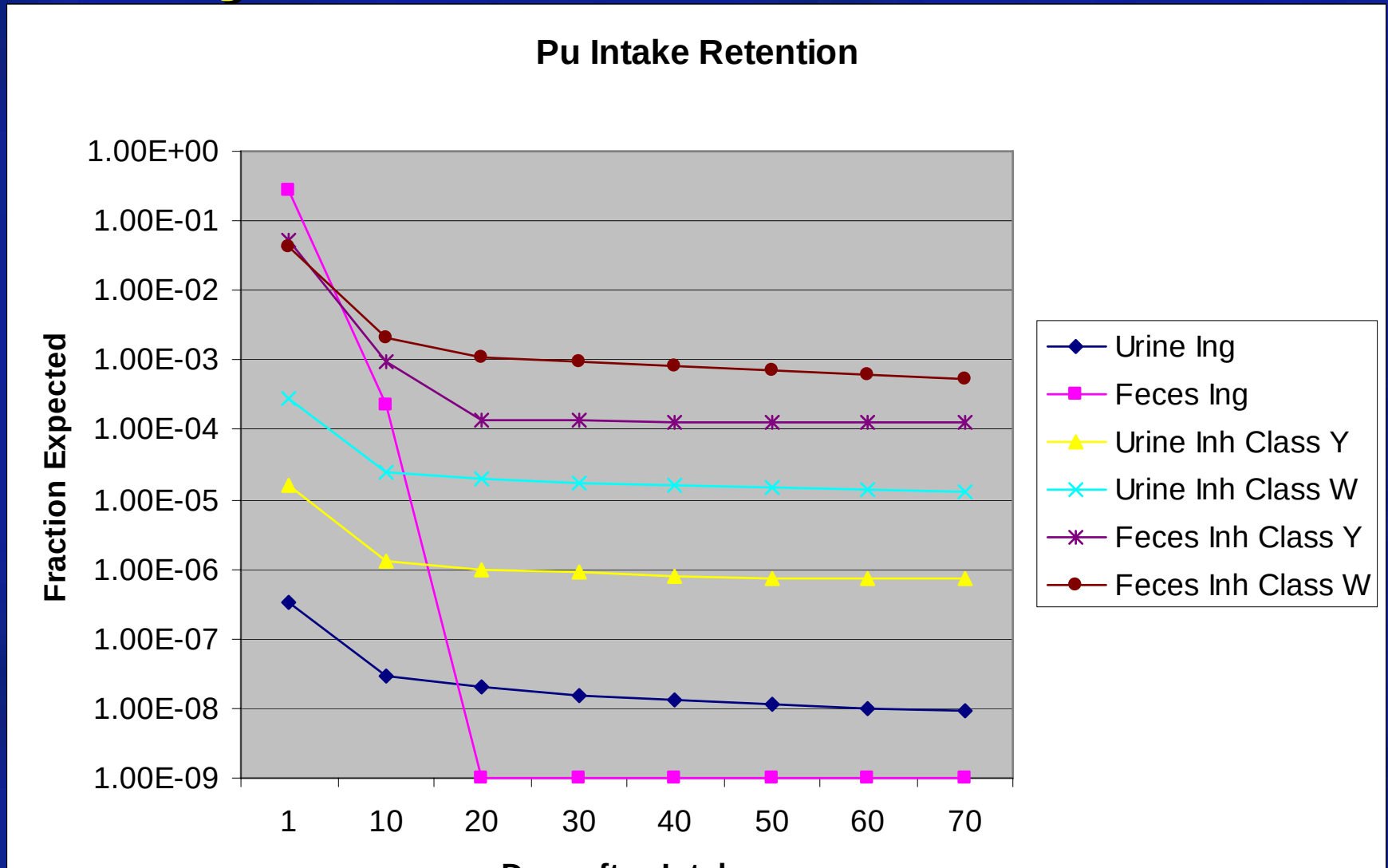
- Minimal Risk Areas:
  - < 200 dpm/100 cm^2
  - General RWPs
- Low Risk Areas
  - 200 – 1000 dpm/100 cm^2
  - Specific –RWPs
- High Risk Areas
  - >1000 dpm/100 cm^2 or Beta/Alpha Ratios < 50/1
  - Specific –RWPs with Higher-Level Controls

Understand Critical Aspects of Internal Dosimetry Assessments

- Perform a Thorough Assessment of Incident
  - Conduct Interviews
  - Evaluate Causes
  - Document Timeline
- Characterize Radionuclide Mix of Potential Intake
- Initiate Timely and Appropriate Bioassays
- Evaluate Data Using Appropriate Models
- Obtain Peer Reviews



In-Vitro Transuranic Dose Assessment: Timely Data is Critical!



Prevent Long-Term Alpha Effects in Nuclear Facilities

- Aggressive Cleanup and Documentation of Spills
  - 10CFR50.75g file
- Good Component Maintenance
- Limitations and Evaluations of Operating when Fuel Leakage is Detected
- Aggressive Routine Plant Decontamination

The End

Questions?