A CASE STUDY IN EVALUATION OF AN INHALATION INTAKE OF POORLY TRANSPORTED PLUTONIUM AT THE SAVANNAH RIVER SITE

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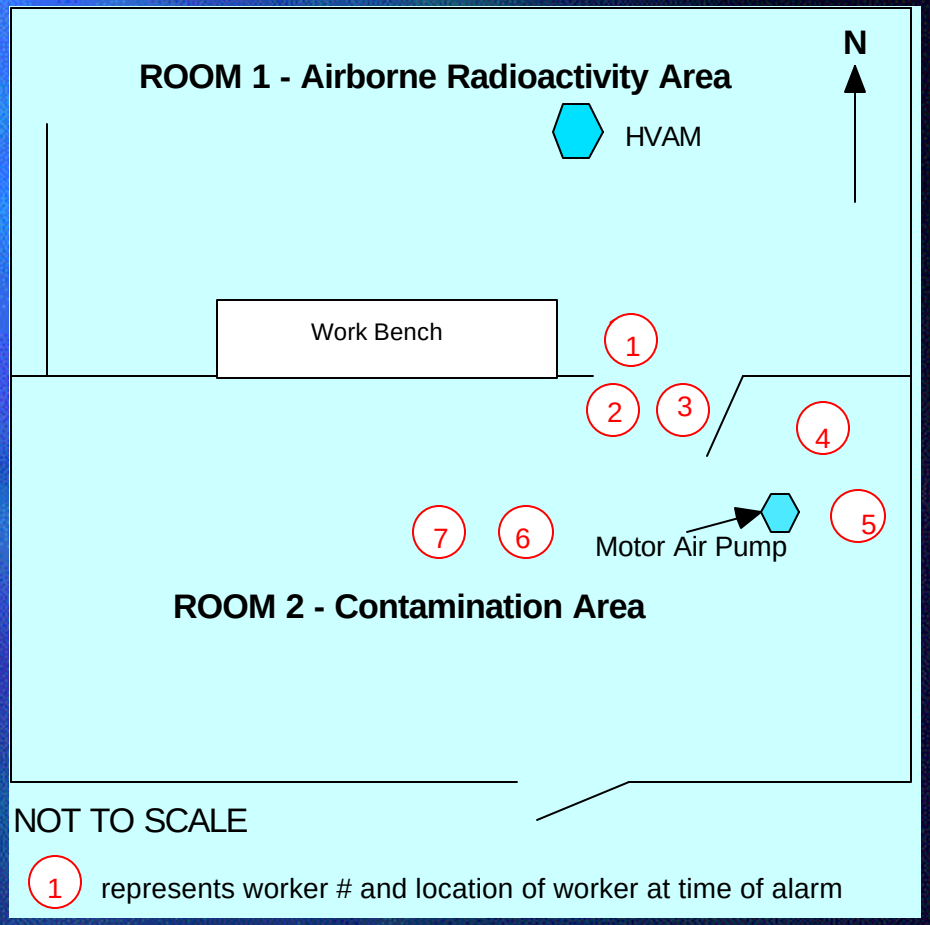
Contamination Event Description

- HVAM (high volume air monitor) alarm while performing routine operations
- Varying levels of external alpha contamination and nasal contamination
- Four workers elect chelation with Ca-DPTA
- Follow-up bioassay programs include 50 minute chest counts, timed urine samples, and fecal samples
- Source of contaminant unknown for a number of weeks



What We Knew Early On

- Isotopic composition of material well characterized from air samplers (activity fractions measured via gamma spec, alpha spec, and mass spec in good agreement)
- Fecal samples were dried & ashed and direct counted. Intakes confirmed for all seven workers.
- Expecting “dpm quantities” of plutonium in initial urine sample of most exposed worker – highest $^{239/240}$Pu concentration via alpha spec analysis: 0.175 dpm/L.
- Only 3 of 7 workers had measurable $^{239/240}$Pu in urine.
- Four of seven workers had measurable ^{241}Am chest burdens

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Unique Challenges

- Chest wall thickness measurements
- Implemented microwave digestion technique for fecal samples
- TIMS for $^{239/240}Pu$ in urine
- First time we have used ICRP 66/67 models for evaluation "of record"
- Lung solubility studies

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Worker 2 Initial Chest Count

```
Spectrum     : DKA200:[USER.INV_L1]   -  -    _STD-L1SUM_199909020725.CNF;1
Title        : Lung Chair #1 STD/L1S:  Geometry
Sample Title: 09/01/99 FBL
Start Time: 2-SEP-1999 07:25:  Sample Time: 2-SEP-1999 07:25:  Energy Offset: 8.18229E-03
Real Time : 0 00:50:00.18      Sample ID  : 8                   Energy Slope : 2.00277E-01
Live Time : 0 00:50:00.00      Sample Type: Individual          Energy Quad  : -5.88844E-08
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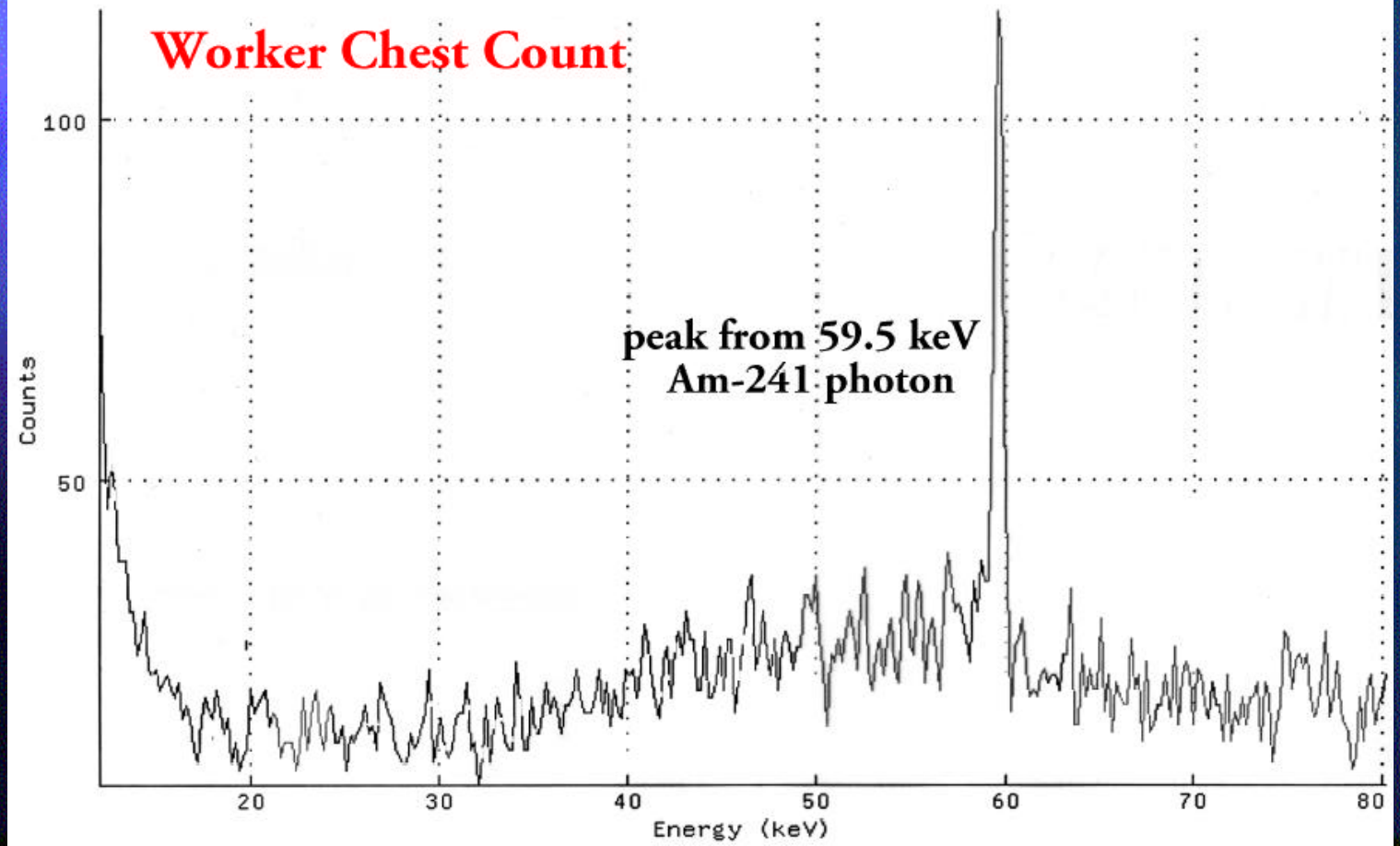

Chest Wall Thickness Measurements

- CWT must be accurately determined for quantitative measurements

- In-vivo software employs an algorithm using height and weight (similar to Fry and Garg) :

$$CWT=-2.0038 + 1.973 * W/H$$

- Ultrasonic CWT measurements made at Medical College of Georgia on four workers with ^{241}Am detected

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Chest counting geometries

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Example of “overlay” for CWT measurements

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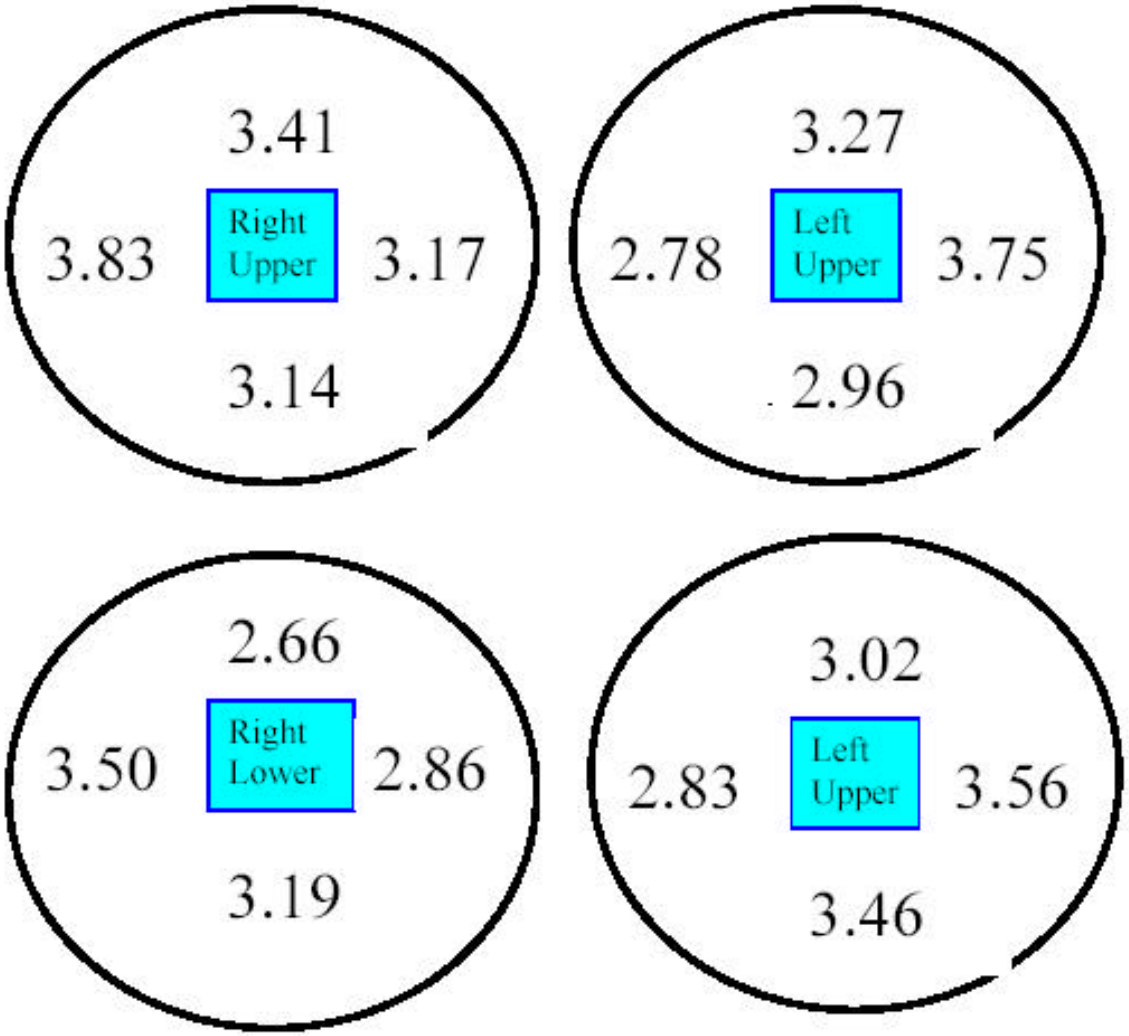

$$x = \begin{pmatrix} 3.83 \\ 3.41 \\ 3.17 \\ 3.14 \\ 2.78 \\ 3.27 \\ 3.75 \\ 2.96 \\ 2.15 \\ 3.02 \\ 3.56 \\ 3.46 \\ 3.5 \\ 2.66 \\ 2.83 \\ 3.19 \end{pmatrix}$$

The measurements may be averaged by taking the linear mean of the individual measurements or the exponential mean of the individual measurements (see Kang, et al. *A Comparison of Techniques in the Assessment of Chest Wall Thickness and Composition* Health Physics 64(4):406-411, 1993).

Chest Wall Thicknesses (cm)

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- IDR 498: 3.1745
- IDR 990: 2.7142
- IDR 991: 3.6452
- IDR 992: 2.3241

MCG

- IDR 498: 3.2150
  1% increase
- IDR 990: 3.8750
  43% increase
- IDR 991: 3.7600
  3% increase
- IDR 992: 4.1800
  80% increase

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Lung Solubility Testing

- Solubility is a critical parameter in transport to other target organs – can have a large effect on delivered dose.
- Performed at Lovelace Respiratory Research Institute
- ICRP 66 lung model allows for use of dissolution data
- Justification for modifications made to dissolution functions and transfer rate constants in trying to fit bioassay data

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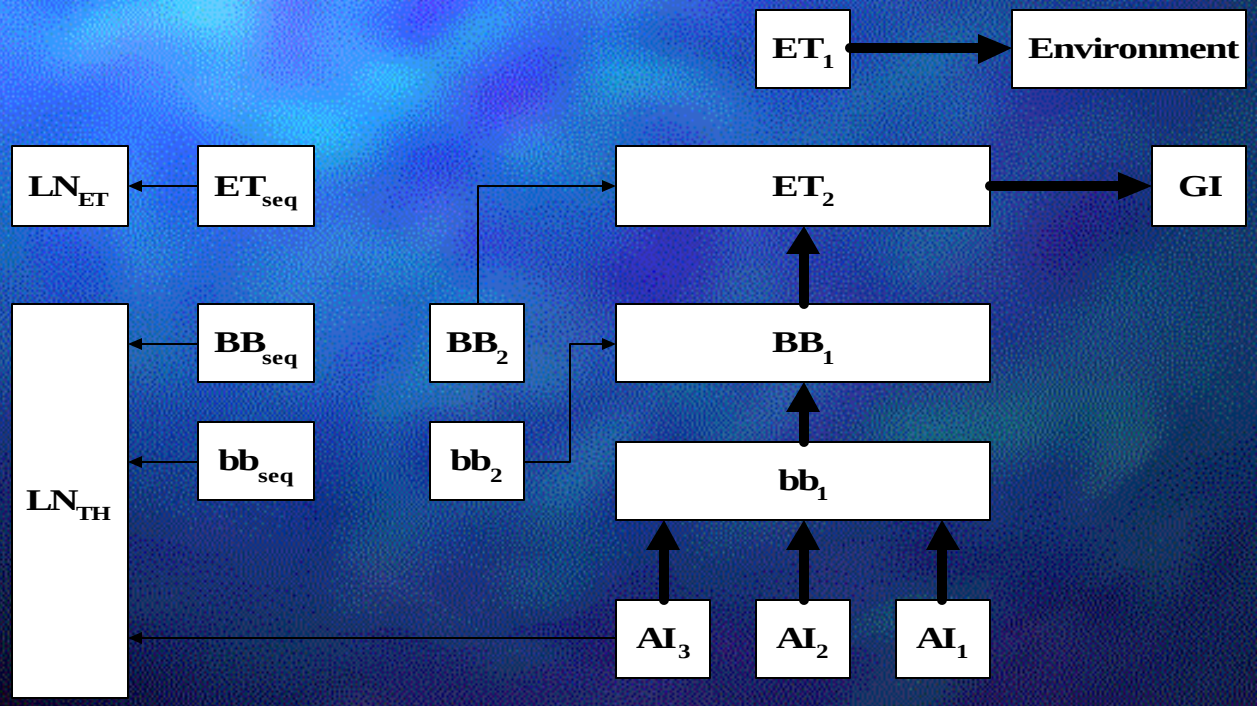
Modifications to Lung Model (Mechanical Clearance)

Modifications made to transfer rate constants:

- AI1 to bb1 reduced by factor of 50
- AI2 to bb1 reduced by factor of 5
- Smallest changes to standard model that would allow adequate fit of chest count data



Modifications to Lung Model (Absorption)

- Modification to dissolution function:
  - f_r (fast absorption fraction) reduced by factor of 5
  - Both rate constants reduced by factor of 10
  - Smallest changes to standard model that would allow the chest count data to agree with the urinary excretion rate

$$r(t) = f_r \cdot e^{-s_r t} + (1-f_r) \cdot e^{-s_s t}$$

Where: r(t) is the fraction of material not dissolved at time t

f_r (0.001)is fraction that dissolves rapidly with rate constant s_r ($100d^{-1}$)

s_s ($0.0001d^{-1}$) is the rate constant for the fraction that dissolves slowly

NOTE: ICRP type S values in parentheses

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Findings of Lung Solubility Test

- 99.93% of Pu dissolved with a half time of 146 years. "Super S" material.

- 0.07% of Pu dissolved with a half time of 0.44 days (f_r < ICRP default value)

- Dissolution test results in good agreement with model modifications.

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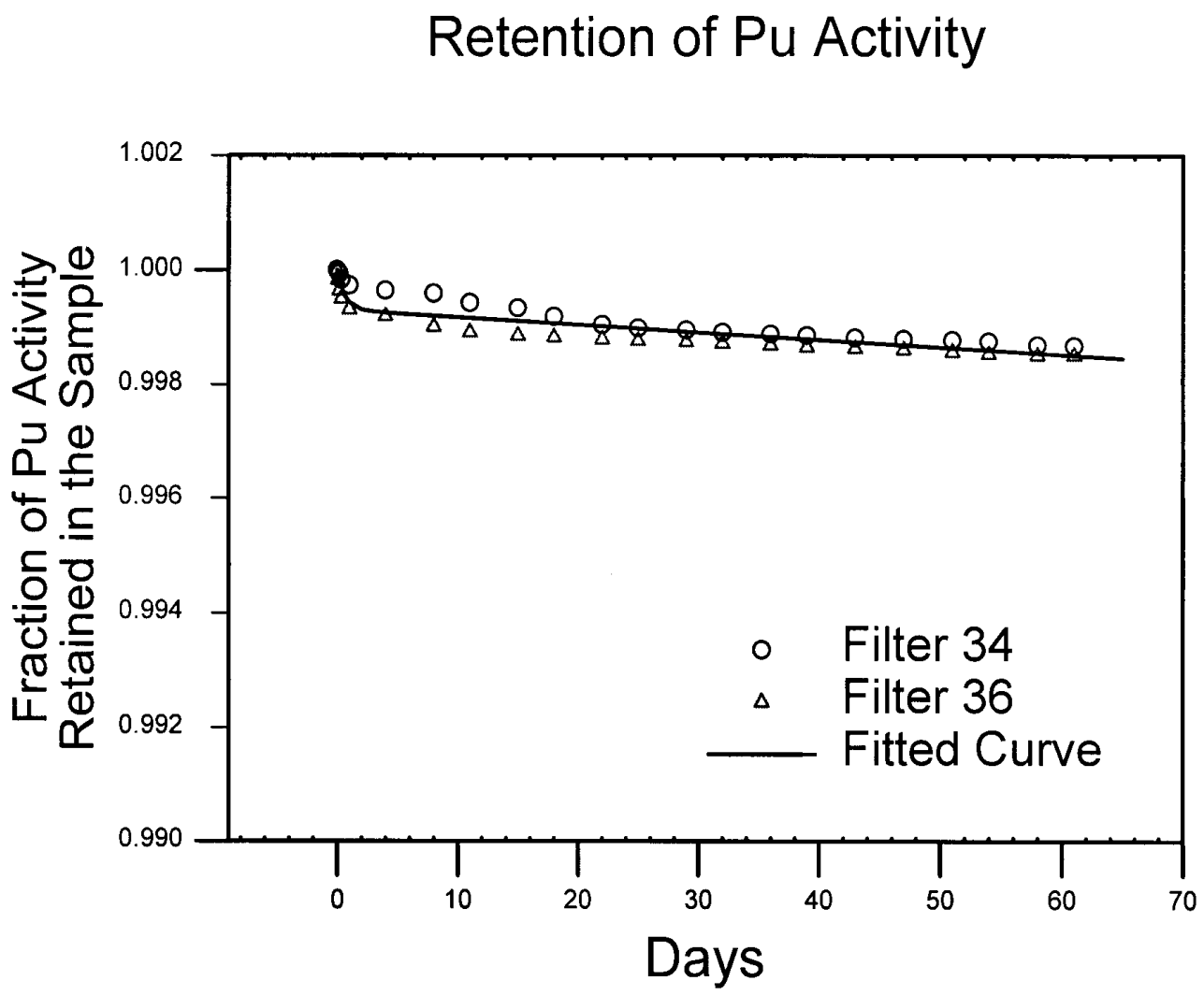
Dissolution of Pu in SUF



Worker 2 CODEs and CEDE

		Organ Dose Equivalents (mrem)					
Dose	Intake		Red		Bone		
From	Date	Gonads	Marrow	Lungs	Surfaces	Liver	
Pu238	9011999	8	29	2453	513	112	
Pu239	9011999	138	475	35968	8922	1939	
Pu241	9011999	17	53	2069	1092	237	
Am241	9011999	33	60	5465	1552	107	
Internal Sources		196	617	45955	12079	2395	
External Sources		245	245	245	245	245	
All sources		441	862	46200	12324	2640	
			Weighted Organ Dose Equivalent (mrem)				
			Red		Bone		
		Gonads	Marrow	Lungs	Surfaces	Liver	CEDE
	CODE	196	617	45955	12079	2395	
	Wt. Factor	0.25	0.12	0.12	0.03	0.3	
	WODE	49	74	5515	362	719	**6719**

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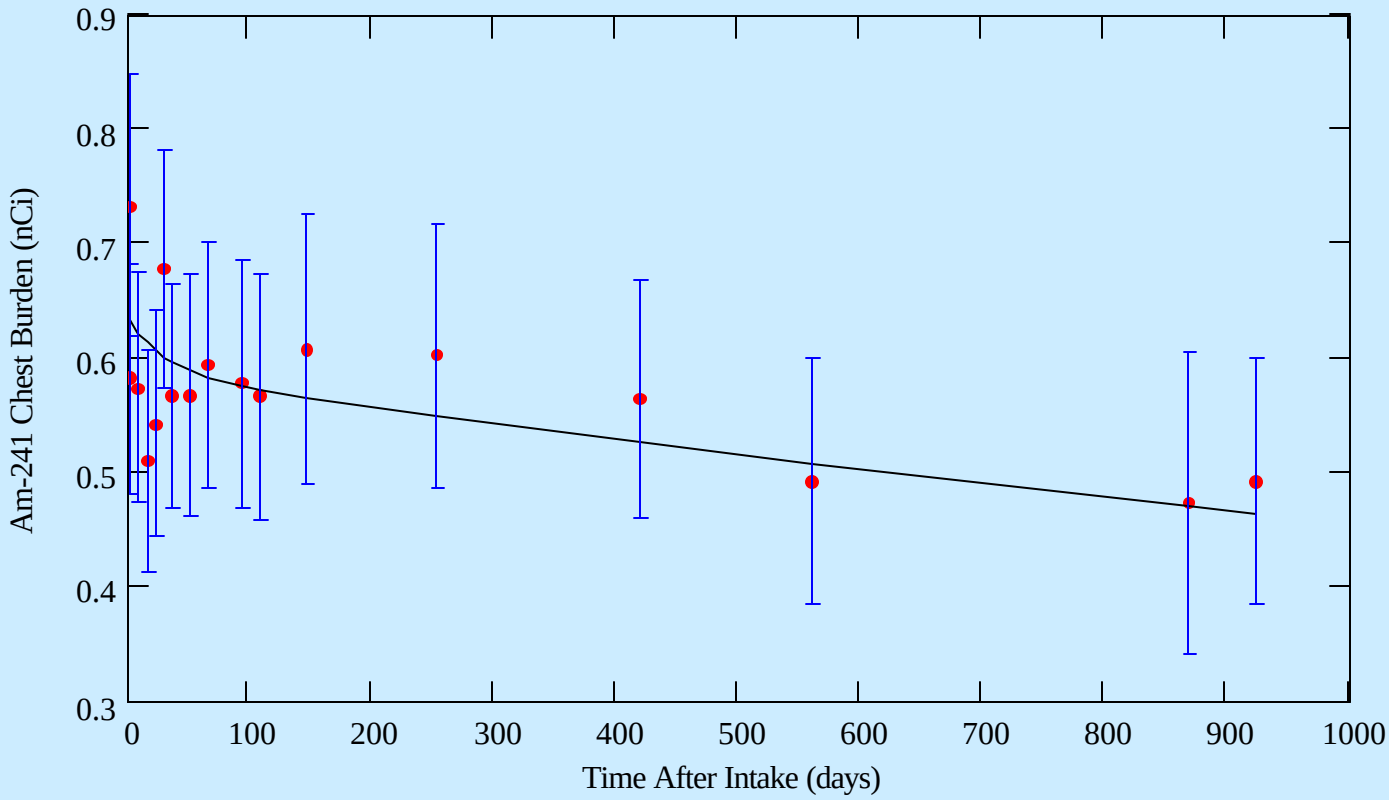
Predicted vs. Observed: ^{241}Am Chest Count Measurements of Worker 2



"Fallout" From This Contamination Event

- Pilot program using new monitoring techniques is ongoing
- Developed capability of performing TIMS measurements at SRS
- Entered into talks with group on site about developing protocols and performing dissolution tests onsite.
- Appreciation for value of chest counting

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