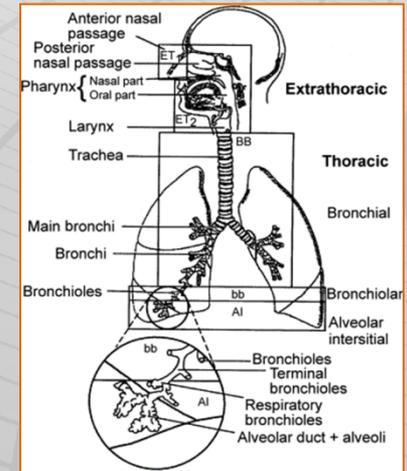# Retention of Soluble Plutonium in the Human Respiratory Tract

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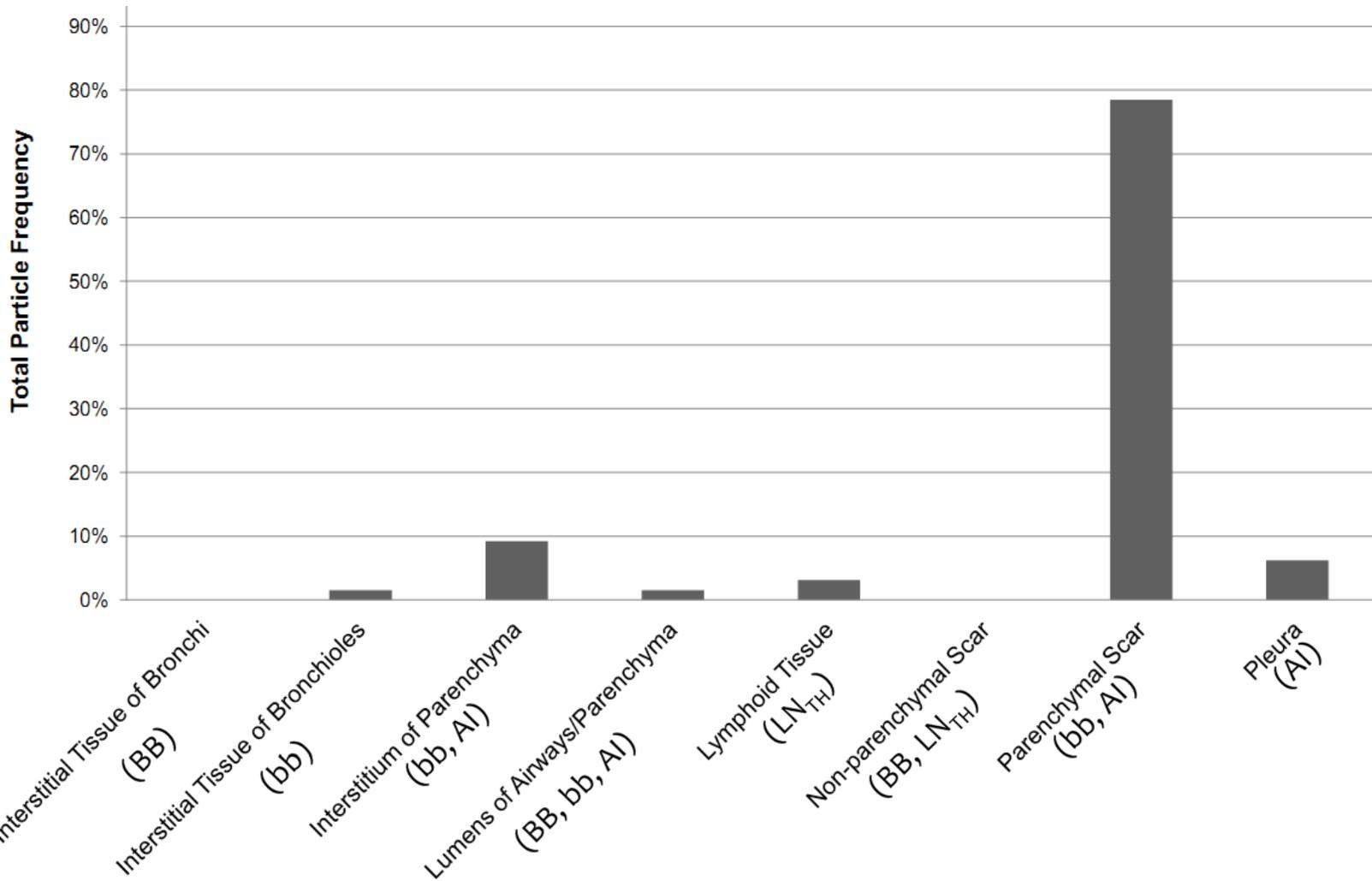
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USTUR Whole-Body Case 0269
(James et al. 2007)

▶ **Operator at REDOX facility**

▶ **Acute inhalation of acidic $^{239}Pu(NO_3)_4$ aerosol mist**

- ■ **Estimated Intake: ~58,000 Bq**

▶ **Chelated:**

- ■ **Ca-EDTA for 6 months immediately after intake**
- ■ **Ca-DTPA 2.5 y after intake**

▶ **Smoker – 1 packs per day**

▶ **Died from adenocarcinoma of prostate**

- ■ **38 y after intake**

Autoradiography: Initial Results
## *(Nielsen et al. 2012)*

Bar chart — Y-axis: Total Particle Frequency (0% to 90%).

X-axis categories:
- Interstitial Tissue of Bronchi (BB)
- Interstitial Tissue of Bronchioles (bb)
- Interstitium of Parenchyma (bb, AI)
- Lumens of Airways/Parenchyma (BB, bb, AI)
- Lymphoid Tissue (LN_{TH})
- Non-parenchymal Scar (BB, LN_{TH})
- Parenchymal Scar (bb, AI)
- Pleura (AI)

Hypothesis

▶ **Distribution and retention of 'bounded' plutonium is non-uniform across the human respiratory tract**
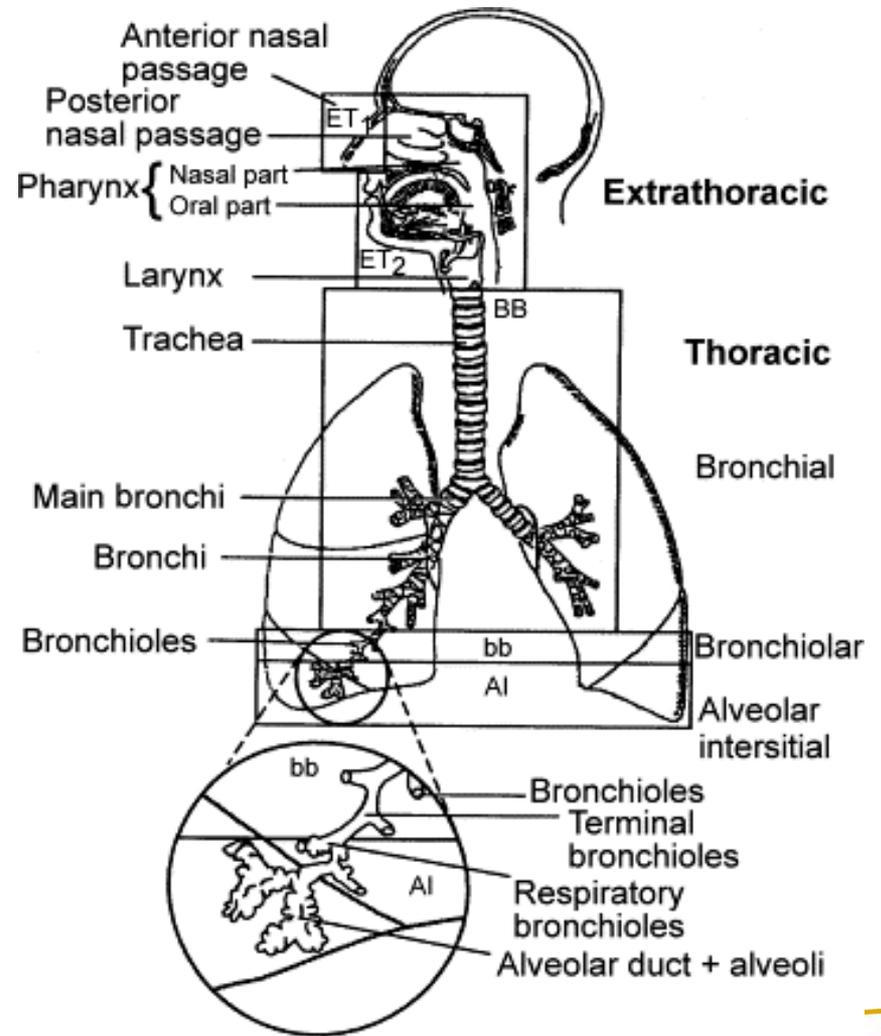
ICRP 66 Human Respiratory Tract Model (HRTM)

Soluble Plutonium Biokinetics

▶ <u>Soluble</u> but ionic:

- Type M – Moderately rapid absorption
- 10% absorbed with halftime of 10 min
- 90% absorbed with halftime of 140 days

▶ <u>Distribution</u> is a function of physical characteristics:

- Particle size, shape, hygroscopicity, quantity of material, morphology and physiology

▶ <u>Retention</u> is dependent upon physicochemical characteristics including:

- Specific activity, solubility, chemical compound

'Bound' Material

▶ **Fraction of dissolved material retained for prolonged periods (f_b)**

▶ **'Bound' material is not cleared by particle transport processes**

▶ **If 'bound' material is present the lung doses increases significantly**

▶ **ICRP Assumption:**

  ■ **In the lung, the 'bound' activity is uniformly distributed**
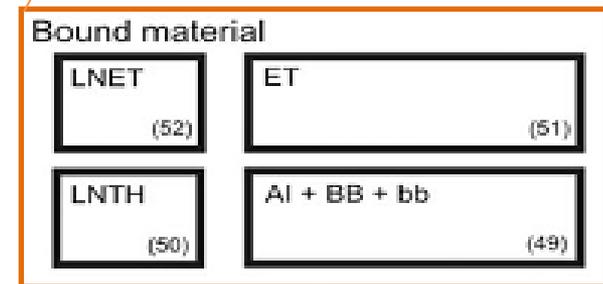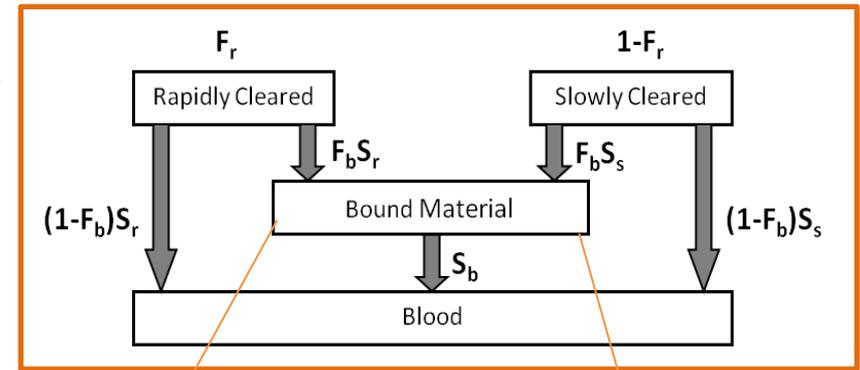
Methods

▶ **Autoradiography: Determine nature of 'bound' material (aggregated/diffuse)**

▶ **Radiochemistry: Characterize the distribution of ^{239}Pu in respiratory tract tissues by assessing the activity concentration across BB, bb, and AI regions**

▶ **IMBA Software: Quantification of bounded fraction (f_b) and uptake rate from bound state (s_b)**

Case 0269 Dissection: Superior Lobe (L)

BB: Generation 2

BB: Generation 3
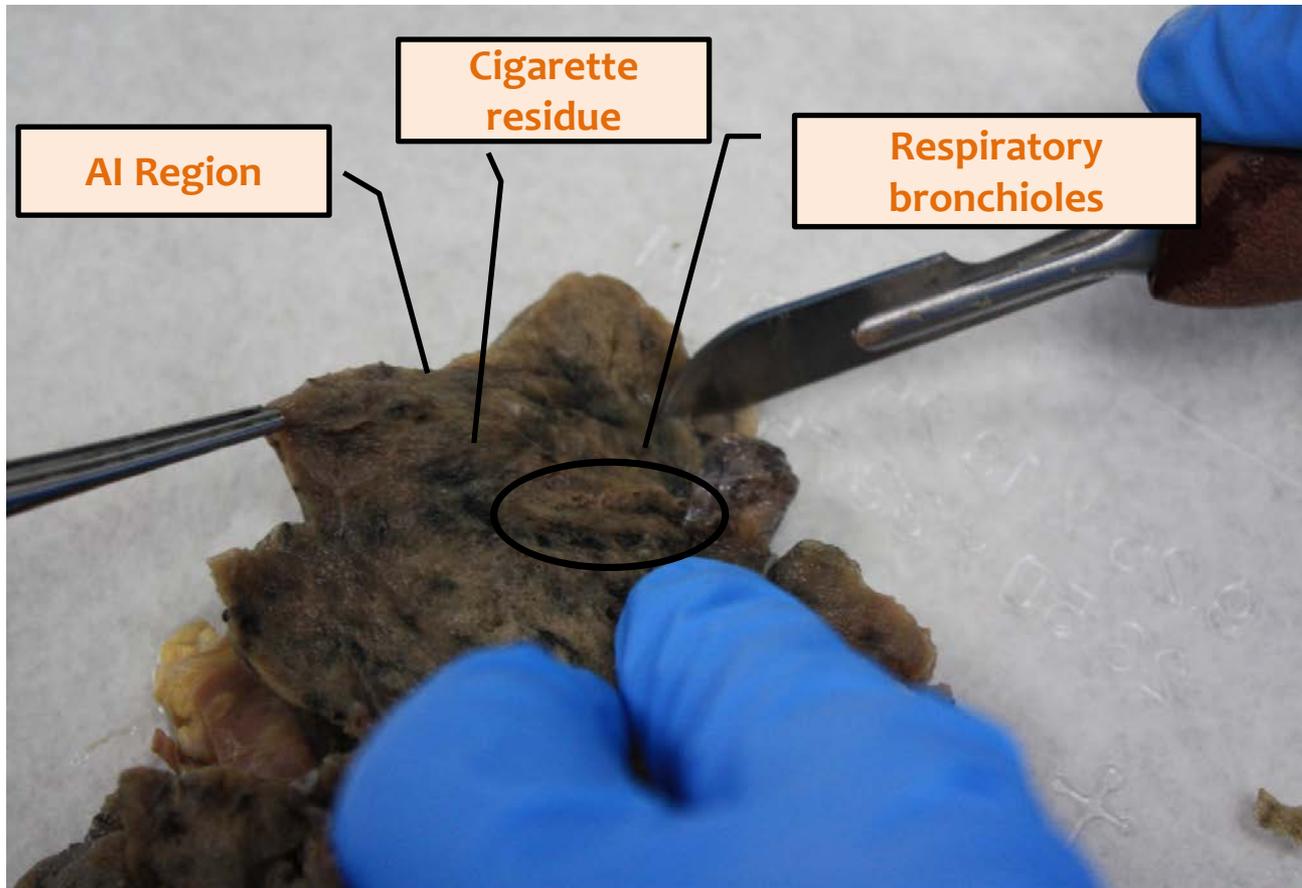
AI Region
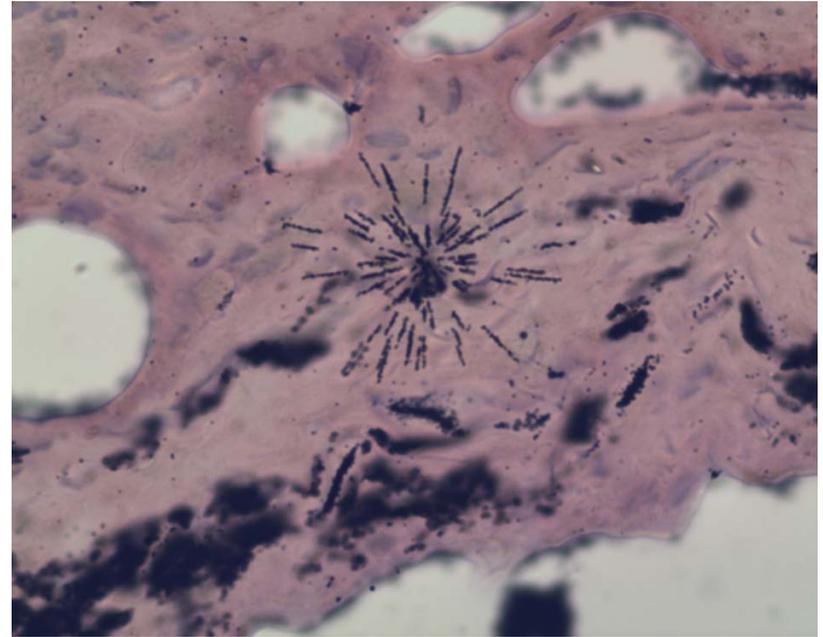
▶ **This photo demonstrates our ability to get a clean excision of BB from the rest of the lobe's tissue (bb & AI)**

▶ **There is no residual of AI tissue once BB is completely excised**

Case 0269 Dissection: Superior Lobe (L)

AI Region

Cigarette residue

Respiratory bronchioles

▶ **Some of the last generations (G) of the bb region (terminal) infiltrate into the AI. Due to the miniscule size of these it is difficult to get them fully separated from the AI. As a result, the AI region contains a small fraction of bb (terminal bronchioles)**

Left Lung: Complete Dissection

▶ **Dissection Time: 3 days**

| BB region | bb region | AI region |

Case 0269: Radiochemistry Results

Tissue	^{239}Pu concentration, Bq kg^{-1} wet
Larynx	31.7±0.5
Trachea	10.5±0.3
Lung (L): BB	30.1±0.2
Lung (L): bb	31.1±0.2
Lung (L): AI	25±0.2
Pulmonary LN (R+L)	41±0.8

Pacific Northwest
NATIONAL LABORATORY

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SOLO/PHE Data Used

Actual measurements

	Activity (Bq)	Sigma[a]
ET2[b]	2.16	0.019
TB[c]	7.69	0.038
AI	16.79	0.113
LNTH	0.45	1.4
Systemic[d]	2120	22.93

[a]Measurement uncertainty assumed to be normally distributed (counting stats only) apart from LNTH, assumed lognormal with GSD of 1.4 (reflects uncertainty in scaling partial LNTH measurement to whole LNTH)
[b]Activity in larynx
[c]Activity in bronchial and bronchiolar region
[c]Combines measurements of skeleton and liver content (note slightly different to previous value due to revised skeleton measurement from USTUR)

SOLO/PHE Parameters

5. How to quantify f_b ?
5.5 Direct measurement in the airways

Public Health England

Case #0269

Parameter	James et al. 2007	Best apriori estimates of parameters[1]
AMAD (µm)	2	4.4
BR (m³h⁻¹)	1.2 (net)	1.2
RF (min⁻¹)	ICRP 66 defaults	16.4
F_n	ICRP 66 defaults	0.82
f_r	0.09	0.17
s_r (d⁻¹)	110	1
s_s (d⁻¹)	0.02	0.001
f_b	0.08	0 to 0.08 (triangular) = 0.023
s_b (d⁻¹)	0.0002	0.0002
K_{FB}	1	1
AI2 to bb ALV to bb (d⁻¹)	0.0017	0.002
f_1 (d⁻¹)	0.0005	0.0005
RT model	ICRP 66	ICRP OIR
Systemic Model	ICRP 67	Leggett et al. 2005

SOLO/PHE Results

Public Health England

SOLO	JCCRER Project 2.4

SOLO

- *HPA re-analysis of PNNL data on long term lung retention in beagle dogs (nit)*

  f_b is 0.2%

- *Re-analysis of the USTUR case #269*
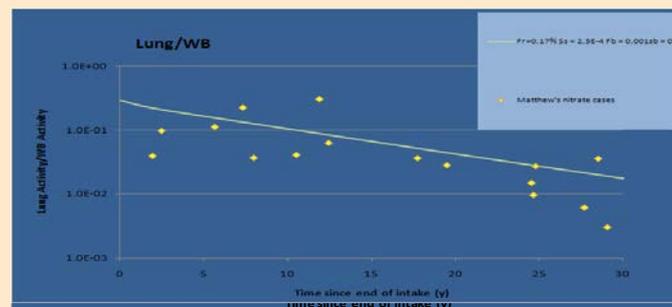
  f_b is 0.4% (.18,.43) $S_b = 0$

- *Direct measurement in the TB region*

  f_b is consistent with above

JCCRER Project 2.4

- *Analysis of 20 Mayak nitrate cases*

  f_b is 0.14% (.01,.3)

- *Previous studies by Khokhrykov et al (2002)*

nrpb

Future Studies...

USTUR Case #	0269	0631	0745
Years Post-intake	38	66	59
Cause of Death	Carcinomatosis of prostate cancer	Complications of Alzheimer's disease	Chronic kidney disease
Smoker/Frequency	Yes/ 1 pack^{-d}	No	Yes/2 pack^{-d}
Chelation Therapy	Ca-EDTA/i.v. Ca-DTPA	None	None
Inhaled Material	Plutonium-nitrate	Plutonium-nitrate	Plutonium-nitrate
Estimated Intake (Bq)	58,000	3,000	3,700