

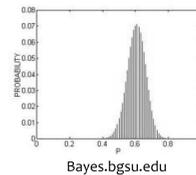
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Introduction

- Inhalation: most common internal contamination pathway for workers.
- Accurate assessment of absorbed doses to the respiratory tract tissues:
 - Important for better understanding of health effects of inhaled radionuclides.
 - Point estimates without uncertainties usually used in epidemiologic studies.
- Bayesian analysis methods:
 - Widely used in internal dosimetry.
 - Enable one to calculate uncertainties as posterior probability distributions.
 - Incorporate all prior knowledge on the exposure (material type, biokinetic model parameters etc.).
- Bayesian uncertainty analysis on lung doses for UKAEA workers:
 - Puncher *et al.* 2011.
 - Indicated the need for further research to better determine the estimates of the critical model parameters.



Objectives

- Calculate the uncertainties on lung doses from inhaled plutonium for further use in epidemiologic studies.
- Investigate the effect of biokinetic models on the dose estimates.

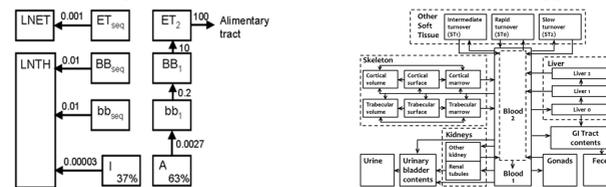
Data Analysis Methods

- IMBA Professional Plus® (Birchall *et al.* 2007)
- IMBA Uncertainty Analyzer
 - Weighted Likelihood Monte-Carlo Sampling (Puncher and Birchall, 2008)



Models

Revised HRTM (Gregoratto *et al.* 2010) Pu systemic model (Leggett *et al.* 2005)



Preliminary Results

The effect of using autopsy tissue analysis results combined with bioassay monitoring data was examined for selected cases.

Posterior Probability Distributions of Equivalent Lung Doses (mSv)

Case #	Years Post-Intake	Urine Data Only		Bioassay [†] + Autopsy [‡] Data		Median Dose Ratio
		Median Dose	GSD	Median Dose	GSD	
Nitrate						
0224	14	395	2.51	230	1.49	0.58
0631*	66	525	2.16	190	2.03	0.37
0795	42	130	2.46	48	1.46	0.37
Oxide						
0028	5	3,410	2.22	9,830	1.27	2.88
0036	6	3,350	2.53	5,050	1.24	1.51
0202	18	6,680	2.64	60,810	1.13	9.10
0407*	43	8,800	3.12	20,920	1.15	2.38
0821	28	5,110	2.66	7,000	1.28	1.37

[†] Urine for nitrates; Urine and *in vivo* lung counts for oxides; [‡] Pu activity in lungs, liver, skeleton; * Autopsy data: skeleton for Case 0631; lung and skeleton for Case 0407

U.S. Transuranium and Uranium Registries (USTUR)



- Is a federally-funded human tissue research program.
- Studies actinides (Pu, Am, U) deposited within the human body – in former nuclear workers with documented exposures.
- Performs complete autopsies on volunteer donors.
- Radiochemically analyzes post-mortem tissue samples for actinide elements.
- Provides long-term follow-up of actinide biokinetics, and potential health effects due to internal depositions of actinides.

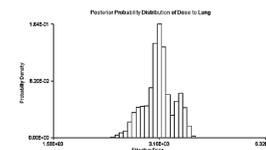
The USTUR has detailed work history, radiation exposure, medical and industrial hygiene records from each registrant's worksite.

Combined with autopsy and radiochemistry results, these form a powerful dataset broadly used to:

- Evaluate and improve biokinetic models.
- Compare pre-mortem estimates with tissue analysis.
- Assess radiation protection standards.

Research Design

- Identify study subjects - donors exposed to Pu exclusively via inhalation.
- Compile data: accident dates and details, material characteristics, bioassay measurements, autopsy tissue sample analysis results etc.
- Group the cases based on solubility class of inhaled material: moderately soluble (nitrates etc.) or insoluble (oxides).
- Reconstruct exposure histories into IMBA Professional Plus®.
- Derive point estimates of intake and lung dose by simultaneously fitting bioassay data and tissue radiochemical analysis results.
- Perform Bayesian analyses using WeLMoS method.
- Derive posterior probability distributions of:
 - Intake
 - Lung Dose
 - Regional Lung Doses: Bb_{sec} , Bb_{bas} , bb , AI
 - Absorption and particle transport parameters



Future Work

- Evaluate all USTUR inhalation cases including donors involved in complex exposure scenarios with multiple significant accidents:
 - Calculate point estimates of lung doses.
 - Perform Bayesian analyses using Extended WeLMoS method.
- Derive material- and worksite-specific prior distributions of lung dissolution parameters.
- Compare the results with corresponding quantities derived for UK workers (Puncher *et al.* 2011).

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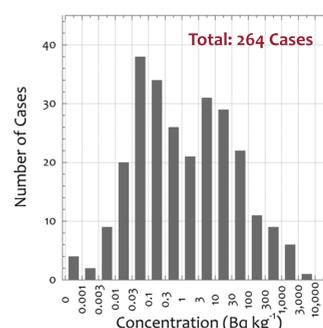
Study Population

Since the establishment in 1968, USTUR received 41 Whole-body and 297 Partial-body donations.

Most of the USTUR Registrants had a number of different exposure incidents involving inhalation, ingestion, and wound intakes with inhalation being the most common pathway.

As of Jan 1, 2013, tissue samples from a total of 264 USTUR Donors were analyzed. The range of ^{239/240}Pu concentrations in lungs spans over 8 orders of magnitude (USTUR 2012).

^{239/240} Pu in USTUR Donors' Lungs	
Median, Bq kg ⁻¹	0.99
Mean, Bq kg ⁻¹	1.28
GSD	29.07
Range, Bq kg ⁻¹	0.0006 – 7,200



Current Study

For initial study, cases with a single well-defined inhalation intake were selected.

Solubility	Chemical Form	# of Cases	Worksite	^{239/240} Pu in Lungs, Bq
Type M	Pu(NO ₃) ₄	3	Han, LA	0.3 to 4
Type S	'High Fired' PuO ₂	5	RFP	730 to 7,500

Prior Distributions used in Initial Calculations

Particle Transport		Absorption to Blood		
Parameter	Prior Distribution [†]	Parameter	Prior Distribution	
			Nitrate [†]	Oxide [‡]
INT _{Dep}	LN(0.37; 2)	f_r	LN(0.17; 2)	U(0.001; 0.02)
ALV to bb, d ⁻¹	LN(0.0027; 3)	s_r , d ⁻¹	LN(1; 4)	U(0.1; 10)
INT to LN _{TH} , d ⁻¹	LN(0.00003; 3)	s_p , d ⁻¹	LN(0.0012; 2.3)	U(0.000001; 0.0001)
K _{PT}	LN(1; 1.73)	f_b^*	Tr(0; 0.08)	n/a

[†] Puncher *et al.* 2011; [‡] Avtandilashvili *et al.* 2013; * $s_b = 0$ (fixed).

The posterior probability distributions were calculated with 10,000 input parameter vector realizations.

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