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Radiation Epidemiology and Dosimetry

# Validation of Bayesian modeling approach of uncertainty in organ doses using post-mortem measurements

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## Introduction

**Purpose of Radiation Epidemiology Studies:** Estimate health risks from ionizing radiation exposure.

- ICRP biokinetic and dosimetric models used for radiation dose assessment. Do not account for dosimetric *uncertainties*.

**Data Sources for Nuclear Workers:**

- Bioassay monitoring data (e.g., urine samples, in-vivo chest counts).

**Bayesian Analysis in Risk Models:**

- Provides a *distribution* of dose estimates instead of a single *point value*.
- Assumes the 'true' dose is part of the posterior distribution.

**Biokinetic Modeling:**

- Predicts time-dependent radionuclide *activity* in organs/tissues.
- Precision in activity prediction reflects uncertainty in *dose* estimation.

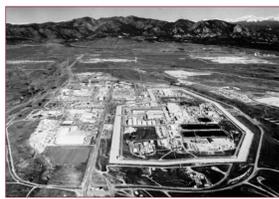
**United States Transuranium and Uranium Registries (USTUR):**

- Unique* human data resource from voluntary posthumous tissue donors.
- Holds records on *exposure history and bioassay data*.
- Conducts *radiochemical analysis* of tissues collected at autopsy.
- 369 registrants, over 70% exposed to *plutonium* (<sup>238</sup>Pu, <sup>239</sup>Pu) via *inhalation*.

## Study Group

Uncertainties in organ activities from internally deposited <sup>239</sup>Pu were evaluated using a group of **20 former nuclear workers** – deceased USTUR Registrants:

- Ten from **Los Alamos National Laboratory (LANL)** exposed to soluble **Pu-nitrate**
- Ten from **Rocky Flats Plant (RFP)** exposed to 'high-fired' **PuO<sub>2</sub>** aerosols



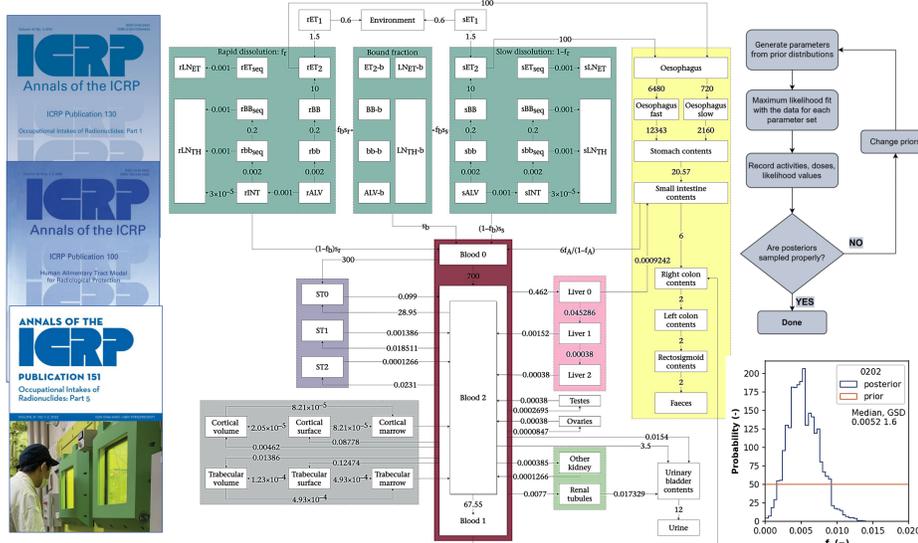
## Methods

**Assumption for intake scenario:** Chronic inhalation during employment

**Biokinetic models:** ICRP 130 HTRM; ICRP 100 HATM; ICRP 141 Pu systemic model

**Software:** USTUR-iRAD, adaptable, object-oriented code, Python 3.9

**Bayesian analysis:** Uncertainties in parameters derived as posterior distributions



**Sensitivity analysis performed to select parameters for Bayesian analysis**

Material solubility parameters,  $f_r$  and  $s_s$ , selected

All other parameters fixed at their ICRP default values

**Calculations:** Latin hypercube sampling ×5000

**Table 1.** Prior distributions for Bayesian analysis

Parameter <sup>†</sup>	Prior distribution
Fraction dissolved rapidly, $f_r$	Uniform (min=0, max=0.2)
Slow dissolution rate, $s_s$ , d <sup>-1</sup>	Lognormal (median=5×10 <sup>-5</sup> , GSD=6) – truncated at 0.002



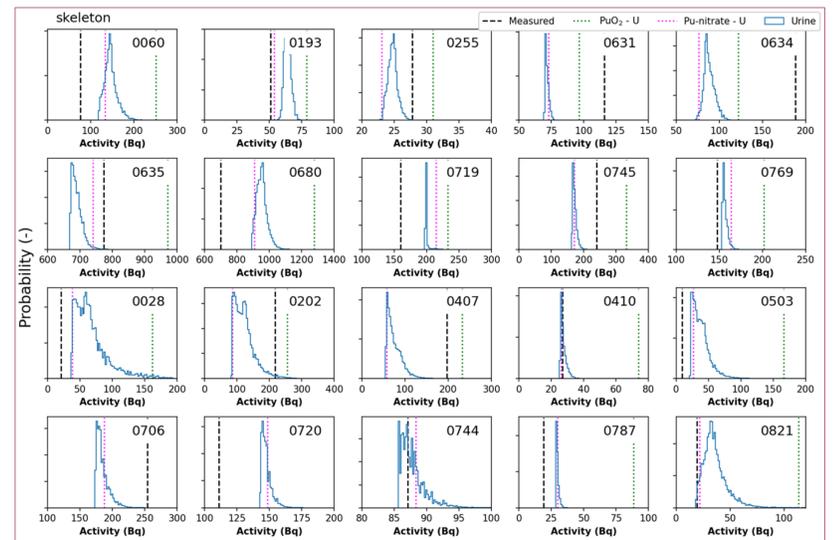
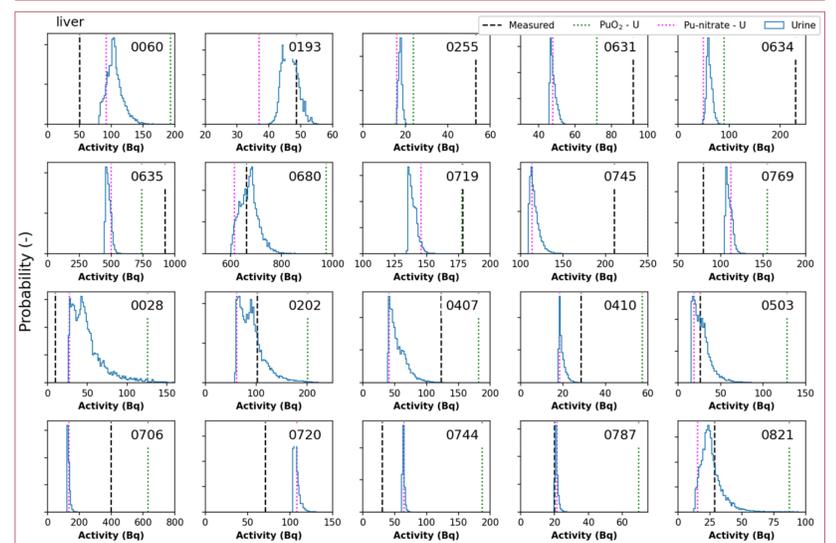
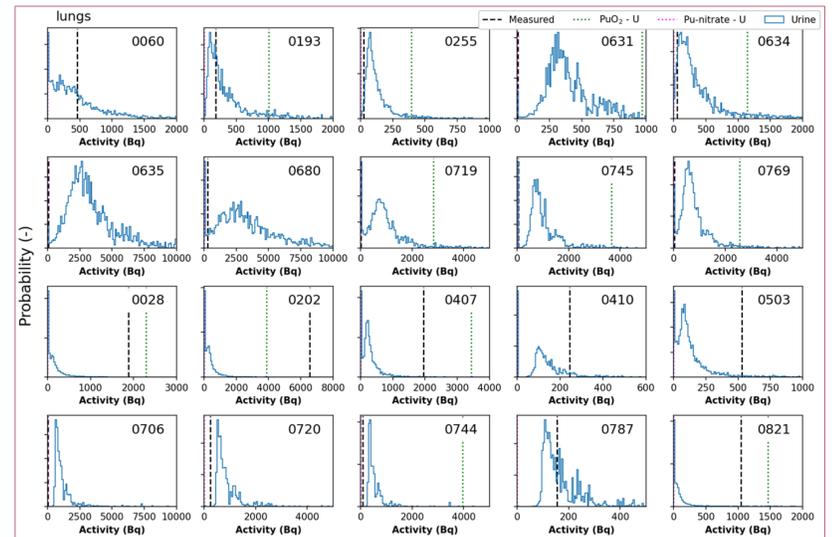
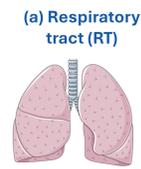
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## Results

### Measured vs. predicted activities in major organs



**Fig. 1.** Posteriors vs. priors vs. point estimates with default parameters. Individual case numbers are identified in each panel

## Conclusions

- Choice of an appropriate prior is critical for accurate interpretation of the data
- Urine bioassay did not provide conclusive information on material solubility parameters ( $f_r$  and  $s_s$ ) for the selected cases.
- Application of current biokinetic models to urine bioassay provides relatively accurate predictions of systemic organ activities (within 60% of measurements); however, the model predictions for the respiratory tract are highly inaccurate.
- A posteriori distributions for systemic organ activities are narrow and often do not cover the measured values: 15 out of 20 for liver, and 18 out of 20 for skeleton.
- The model predictions are not conservative in some cases, which might pose a concern for radiation protection if not considered.

## Acknowledgements

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