



WASHINGTON STATE
UNIVERSITY

Uncertainty in Plutonium Internal Dose Estimates for Rocky Flats Workers

Martin Šefl¹, Maia Avtandilashvili¹, Joey Y Zhou², Sergei Y Tolmachev¹

¹United States Transuranium and Uranium Registries, College of Pharmacy and Pharmaceutical Sciences

²Office of Domestic and International Health Studies, United States Department of Energy

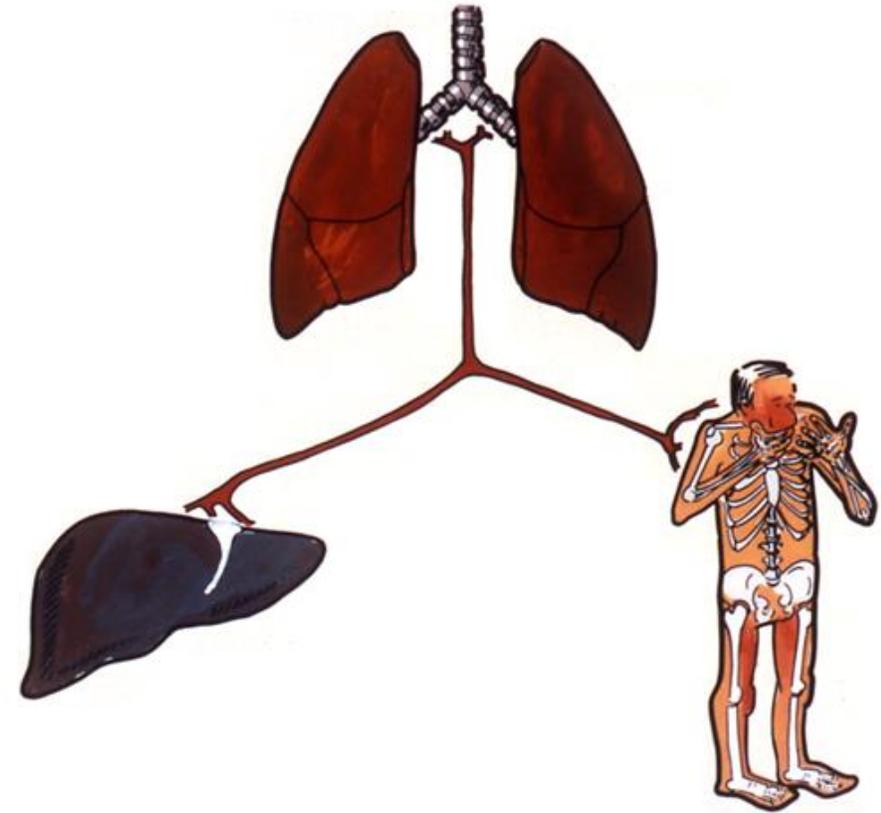
Motivation

- In radiation epidemiology, worksite records and bioassay measurements are used to estimate the radiation doses
- Post-mortem tissue/organ analyses can be used to evaluate the accuracy of the reference biokinetic and dosimetric models used for radiation epidemiology



Objectives

- Comparison of plutonium activity in **liver+skeleton** predicted from **urine bioassay and chest counts** with post-mortem radiochemical analyses to evaluate biokinetic models
- Comparison of doses predicted using urine bioassay to those predicted using both **urine bioassay, chest counts** and **post-mortem tissue analysis** results



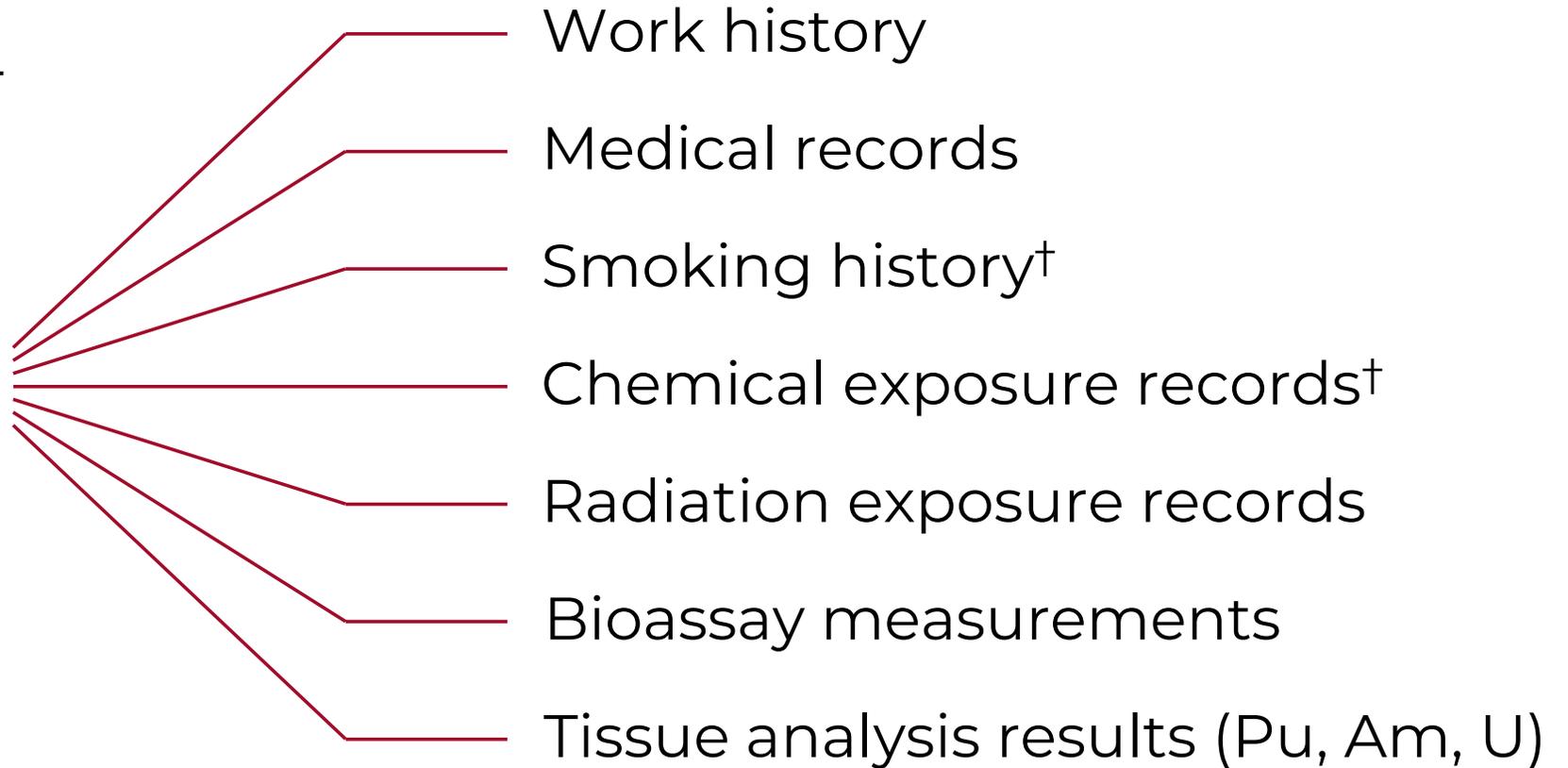
Unique Data Resource



12



354

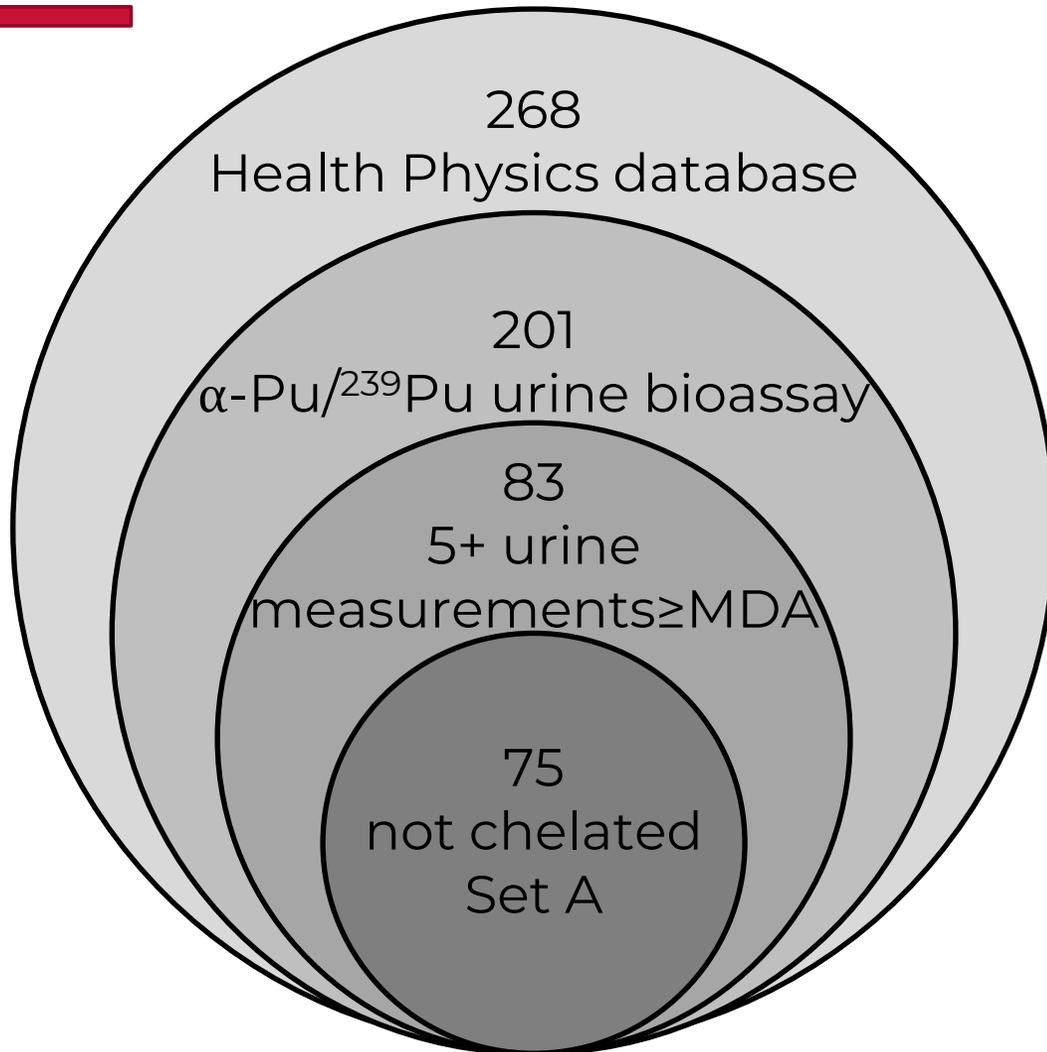


† - self-reported data

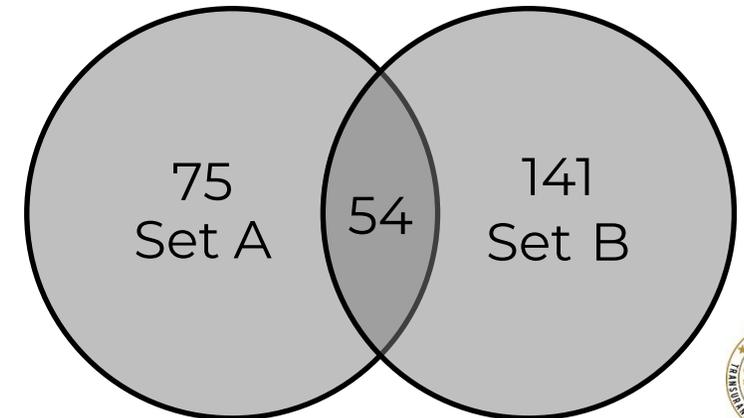
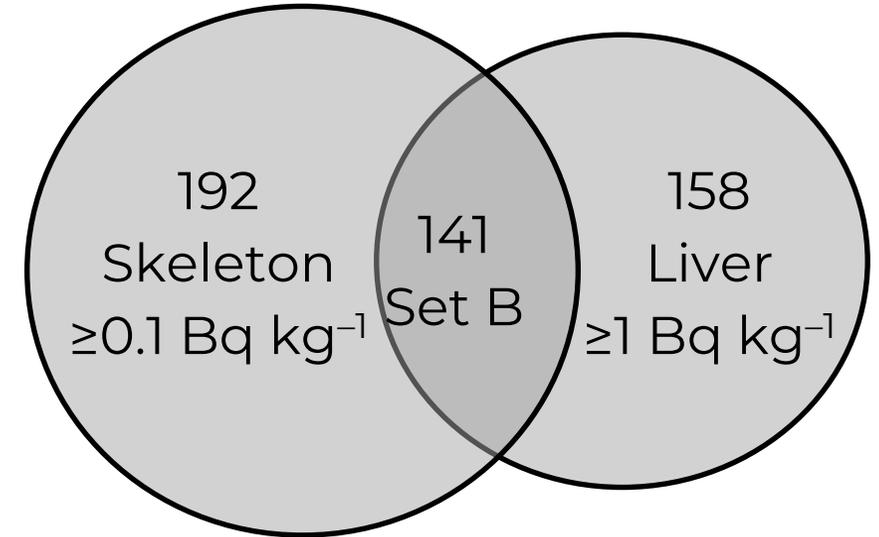




Study Case Selection Criteria



Radiochemical analysis



Finished: Manhattan Project Workers

- 11 individuals exposed in 1940s
- Mostly soluble $\text{Pu}(\text{NO}_3)_4$

PLOS ONE

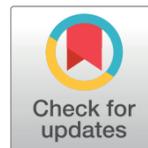
RESEARCH ARTICLE

Plutonium in Manhattan Project workers: Using autopsy data to evaluate organ content and dose estimates based on urine bioassay with implications for radiation epidemiology

Martin Šefl^{1*}, Joey Y. Zhou², Maia Avtandilashvili¹, Stacey L. McComish¹, Sergei Y. Tolmachev¹

1 United States Transuranium and Uranium Registries, College of Pharmacy and Pharmaceutical Sciences, Washington State University, Richland, Washington, United States of America, **2** Office of Domestic and International Health Studies, United States Department of Energy, Washington, DC, United States of America

* martin.sefl@wsu.edu



Šefl et al. Plutonium in Manhattan Project workers: Using autopsy data to evaluate organ content and dose estimates based on urine bioassay with implications for radiation epidemiology. PLOS One 16(10): e0259057; 2019.



Fire of 1965 at Rocky Flats plant

- Maintenance operation unplugging oil coolant line on a glove box, extinguished quickly
- Air contamination over 6,500 m² with air samplers ranging from 3.7×10^{-2} Bq m⁻³ to 3.7×10^4 Bq m⁻³
- Rapid spread – many workers weren't wearing any protection, 400 monitored, 25 exceeding the maximum permissible body burden
- Highest exposed workers had treatment with Ca-DTPA which stopped after 4-5 days for not being considered effective

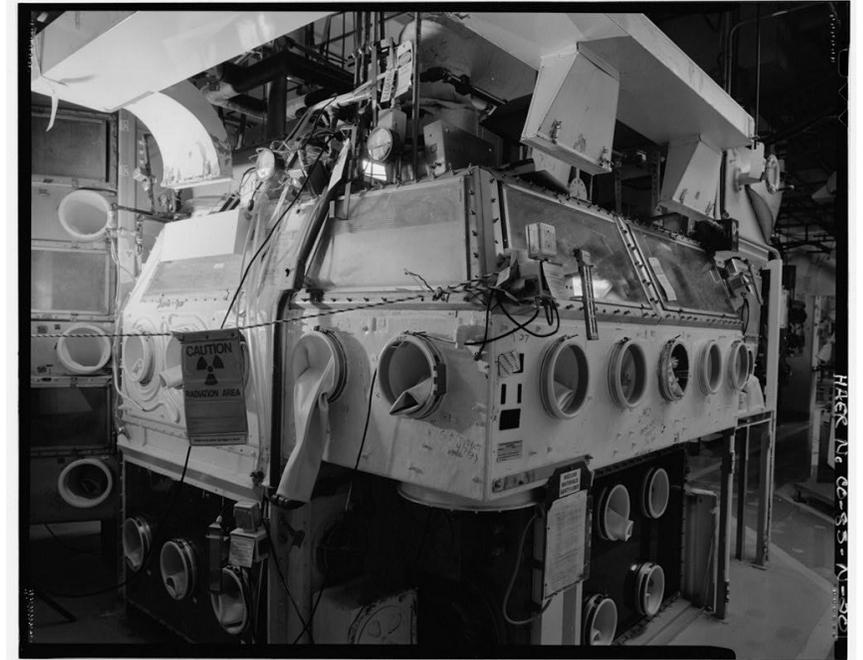


https://commons.wikimedia.org/wiki/File:1969_Rocky_Flats_Fire_-_destroyed_glove_box.jpg



Pu Refractory Particles

- 23 USTUR registrants involved
 - Studied cases: 9 (4 whole-body, 5 partial-body)
- ‘High-fired’ PuO₂ aerosols
 - Generated at 1,800°C
 - Insoluble
 - 1 μm AMAD



<https://www.loc.gov/resource/hhh.co0855.photos/?sp=20>



Next Studied Group: Fire of 1965

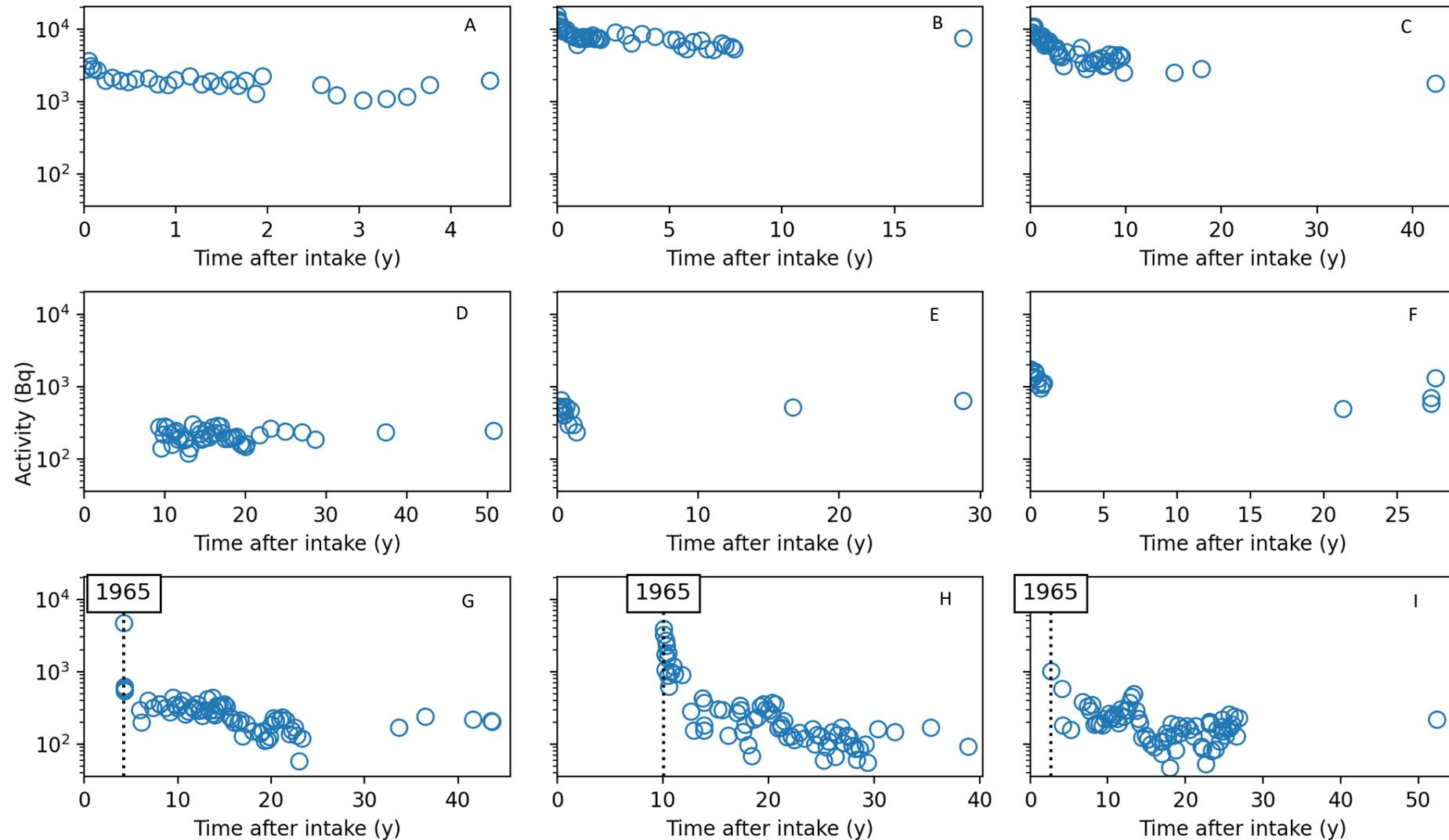
- Studied cases: 9 (4 whole-body, 5 partial-body)
- Intake regimes:
 - ✓ Single acute inhalation – 6 cases
 - ✓ Single acute inhalation and wound before the fire – 2 cases
 - ✓ Two acute inhalations – 1 case
- Post-mortem organ activity:
 - ✓ Liver: 9.4–123 Bq
 - ✓ Skeleton: 9.2–215 Bq
 - ✓ Lungs: 92.9–7,540 Bq



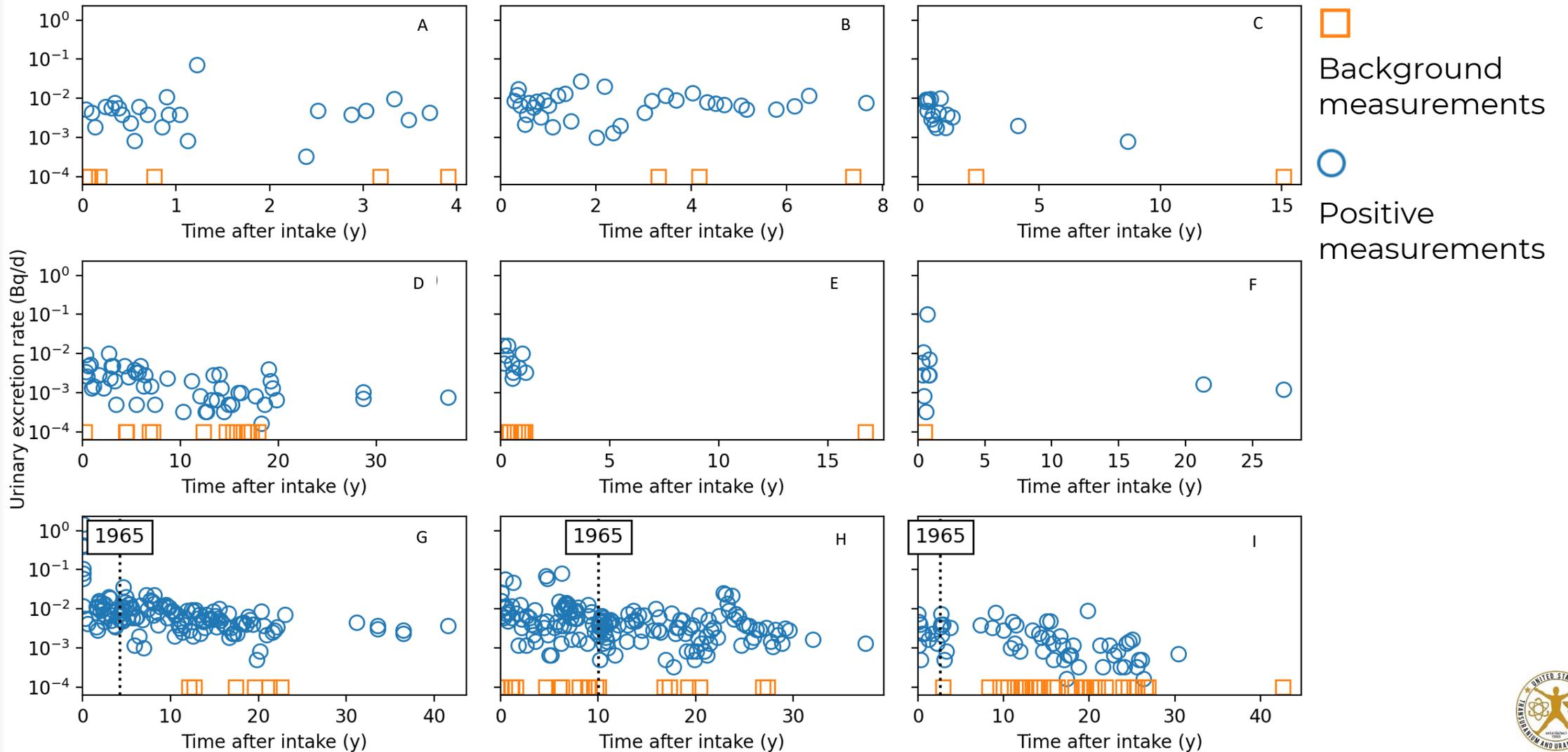
<https://coloradoencyclopedia.org/article/rocky-flats-nuclear-facility>



Data: Chest Counts



Data: Urine Bioassay



Data: Post-mortem Organ Activities

- Organ activity (Bq) = Concentration (Bq/kg) × Weight (kg)
- Liver: concentration and weight measured
- Skeleton: concentration and weight estimated

Skeleton	Activity concentration based on analysis of	Weight
Whole body	70–90 bone samples (right side of the skeleton)	Measured
Partial body	4–8 bone samples [†]	Estimated [‡]

[†] - Šefl M, Zhou JY, Avtandilashvili M, Tolmachev SY. *Latent Bone Modelling for Estimation of Plutonium Concentration in Skeleton of Former Nuclear Workers*. Radiat Prot Dosim. (In Press, 2023)

[‡] - Avtandilashvili M, Tolmachev SY. *Modeling the Skeleton Weight of an Adult Caucasian Man*. Health Phys. 117(2):149–155; 2019.



Bias in Organ Activity

- Predict plutonium activities A_U (Bq) in lungs, liver+skeleton (to eliminate inter-subject liver and skeleton variability) at the time of death
- Compare to measured post-mortem liver+skeleton activity A_M with predicted value based on urine and chest counts

$$\text{Absolute Bias(\%)} = \left| \frac{A_U - A_M}{A_M} \right| \times 100$$

$$\text{Bias(\%)} = \frac{A_U - A_M}{A_M} \times 100$$



Bias in Activity Predicted using Bioassay

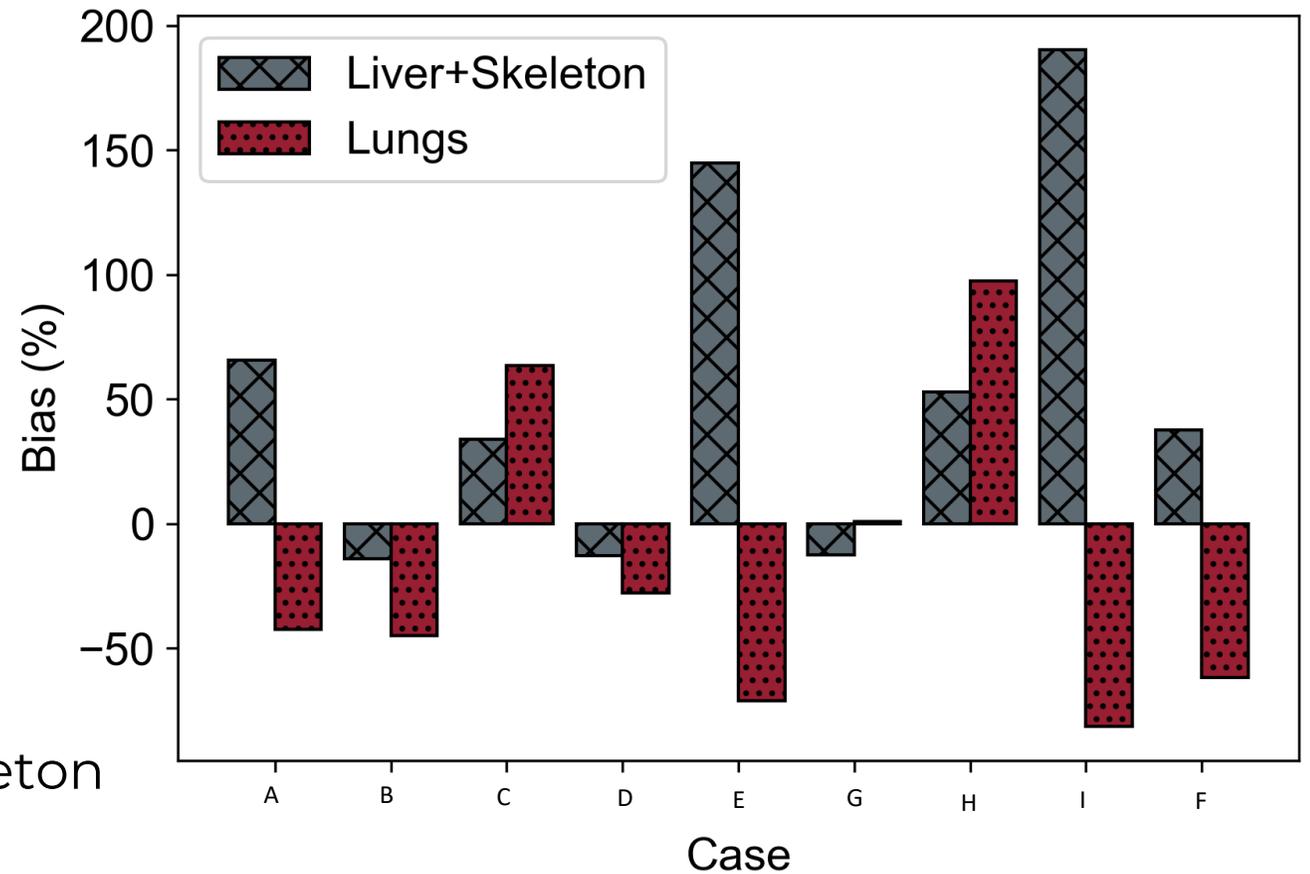
Absolute bias range (%)

Liver+Skeleton	12-190
Lungs	1-98

Mean bias (%)

Liver+Skeleton	54±72
Lungs	-19±62

- Manhattan project workers: average bias for the liver+skeleton was $-4\pm 51\%$ *



*Šefl et al. Plutonium in Manhattan Project workers: Using autopsy data to evaluate organ content and dose estimates based on urine bioassay with implications for radiation epidemiology. PLOS One 16(10): e0259057; 2019.



Bias in Committed Equivalent Dose Organ

- Reference “best estimate” using all available data, urine bioassay, chest counts and post-mortem liver+skeleton activity – $H_{T,A}(50)$
- $H_{T,U}(50)$ – using all available urine data and chest counts

$$\text{Absolute Bias(\%)} = \left| \frac{H_{T,U} - H_{T,A}}{H_{T,A}} \right| \times 100$$

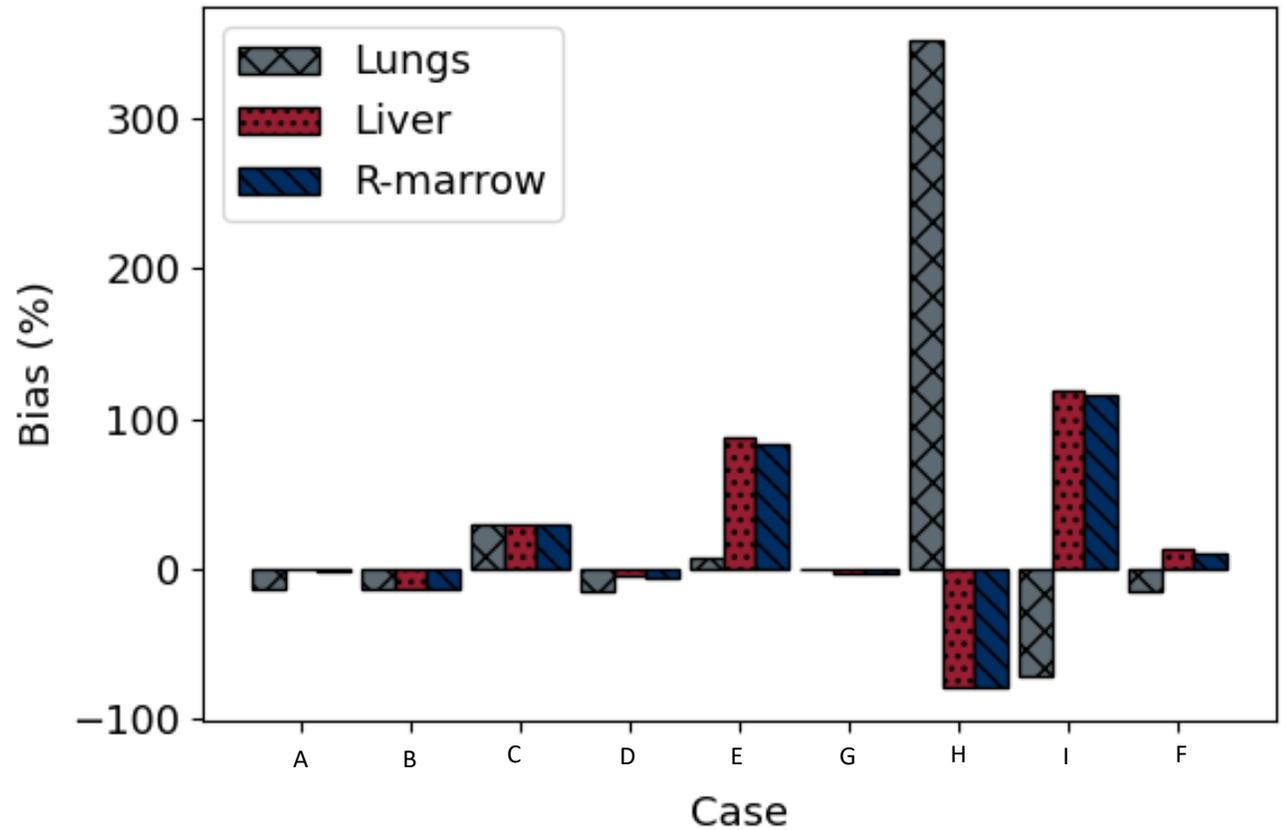
$$\text{Bias(\%)} = \frac{H_{T,U} - H_{T,A}}{H_{T,A}} \times 100$$



Bias in Committed Equivalent Dose

Absolute bias range (%)	
Lungs	0-352
Liver	0-119
R-marrow	1-116

Mean bias (%)	
Lungs	29±124
Liver	17±58
R-marrow	15±56



Conclusions

- On average, current biokinetic models overestimated the **liver+skeleton** activity by 54% and underestimated the **lungs** activity by 19%
- Maximum bias was 190% for the **liver+skeleton** and 98% for the **lungs**
- Using post-mortem tissue measurements in addition to bioassay for organ dose calculations decreased the predicted dose values by 16, 17, 29% for **r-marrow, liver, and lungs**, respectively



Thank you for your attention

