

# Applicability of a unique USTUR dataset: Female nuclear worker treated with chelation therapy after plutonium exposure via inhalation

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# U.S. Transuranium and Uranium Registries (USTUR)

- The USTUR is a federal-grant program funded by U.S. Department of Energy and operated by College of Pharmacy and Pharmaceutical Sciences at Washington State University
- The Registries was established in 1968 to study the biokinetics and internal dosimetry of actinides - such as uranium, thorium, plutonium, and americium - in occupationally exposed individuals who volunteer their bodies for scientific use posthumously (partially or entirely)



# Uniqueness of the Dataset Used in This Study

- The uniqueness of this USTUR dataset is due to:
  - (i) early and long-term data from a female with plutonium intake;
  - (ii) bioassay data following chelation therapy for a female;
  - (iii) fecal measurement results
- This dataset can be used in chelation modeling studies, biokinetic model development, and internal dosimetry refinement

# Studied Case: Publications

Radiation Protection Dosimetry Vol. 104, No. 3, pp. 231-236 (2003)  
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## PLUTONIUM CONTENT OF HUMAN PLACENTAL TISSUES AFTER OCCUPATIONAL EXPOSURE

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**Abstract** — The placenta and umbilical cord received an accidental inhalation intake to be about 73 Bq Class W plutonium per body content at the beginning of pregnancy. The placenta and cord from this pregnancy (Case 0835), were divided into two laboratories. Placental  $^{239}\text{Pu}$  concentrations were several-fold greater than for other populations. There was no elevated cord to placenta ratios. The values of 0.16 and 0.27 for placental to cord ratios are higher than the values of 0.1 the ICRP calculated for intake

### INTERNAL DOSIMETRY

Tuesday, 12 June 2001

Room: CC 230B

8:15-11:45 am

### TAM-B.1

**FETOPLACENTAL DOSIMETRY OF PLUTONIUM BURDENS INCURRED PRIOR TO PREGNANCY.** \* M. Sikov and J. Russell (United States Transuranium and Uranium Registries, Washington State University, 2710 University Drive, Richland, WA 99352)

Concern with determining and controlling radiation doses associated with exposure of potentially pregnant women to radioactive materials in the workplace and in the environment have led to studies of fetoplacental disposition in several species of experimental animals. These studies have quantified placental transfer from the

USTUR-0094-97

## United States Transuranium and Uranium Registries



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ANNUAL REPORT  
OCTOBER 1, 1996 - SEPTEMBER 30, 1997

December 1997

Compiled and Edited by: R.L. Kathren and S.M. Ehrhart

S. Bao, G.E. Dagle, S.M. Ehrhart, R.H. Filby, R.E. Filipy, S.E. Glover, B.S. Jacobson, C.L. Love, M.V. Pham, J.J. Russell, M.D. Shreve, D.B. Stuit, R.G. Thomas, W.R. Wilson

USTUR-0072-97

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Contributors: S. Bao, A.L. Brooks, G.R. Dagle, R.H. Filby, R.E. Filipy, S.R. Glover, B. Gold, R.L. Kathren, C.L. Love, T.P. Lynch, M.V. Pham, J.J. Russell, D.B. Stuit

# Purpose of This Study

- Previous works have not published the radiobioassay measurements, thus, we intend to publish it in the scientific literature
- It is the first time that a study shows the modeling of this dataset with a focus on chelation modeling

# Case Description

- This is a historical case from the USTUR database
- A female nuclear worker was exposed to plutonium-ameridium mixture via acute inhalation
  - The intake occurred even though she was wearing respiratory protection
- Immediately after her exposure, she received extensive skin decontamination, was medically treated with chelation therapy, and provided bioassay samples
  - A total of 13 fecal and 24 urine samples was collected and analyzed for plutonium and ameridium from day 0 until day 20
  - She was followed-up for 14 years for plutonium urine bioassay measurements

# Medical Treatment: Chelation with Ca-DTPA

- Chelation therapy involves the administration of chelating agents such as Ca-DTPA to remove heavy metals (e.g., plutonium) from the body
  - The goal is to reduce the internal radiation dose
- The worker received intramuscular injection of 1 gram of Ca-DTPA on day 0, 5 and 14 post-intake



# Bioassay Data Used

- In vitro: urine (19)
- In vitro: fecal (12)
- In vivo: lung count (1)
- Total data points: 32

Bioassay data	Affected by chelation?	Number of data (nData)
Urine 24 h	Yes	6
Urine 24 h	No	13
Feces 24 h	Yes	12
Lung	No	1

# Biokinetic Models

- All biokinetic models were constructed and linked together in IDode software  
(*Miller et al. 2012*)

Model Type	Models used (all connected with each other)	Varied parameters during fit
Biokinetic	ICRP 30 Gastrointestinal (GI) tract model	None (all fixed)
Biokinetic	ICRP 66 Inhalation model	Intake and solubility parameters
Biokinetic	Plutonium systemic model ( <i>Leggett et al. 2005</i> )	None (all fixed)
Biokinetic	Chelation model ( <i>Dumit et al. 2020</i> )	None (all fixed)

Miller et al. Health Physics 103:484-494; 2012  
Leggett et al. Radiation Research 164(2): 111-122; 2005  
Dumit et al. Health Physics 119(6):715-732; 2020

# Usefulness of a Chelation Model

- Chelation treatment enhances Pu rate of excretion
  - The standard biokinetic models cannot describe the bioassay data affected by chelation
  - Only bioassay data non-affected by chelation can be included in the biokinetic modeling
- A new chelation model was used in this work
  - All bioassay data, affected and non-affected by chelation treatment, can be included in the biokinetic modeling

SPECIAL COLLECTION OF PAPERS

## Development of a New Chelation Model: Bioassay Data Interpretation and Dose Assessment after Plutonium Intake via Wound and Treatment with DTPA

Dumit, Sara<sup>1</sup>; Miller, Guthrie<sup>2</sup>; Klumpp, John A.<sup>1</sup>; Poudel, Deepesh<sup>1</sup>; Bertelli, Luiz<sup>1</sup>; Waters, Tom L.<sup>1</sup>

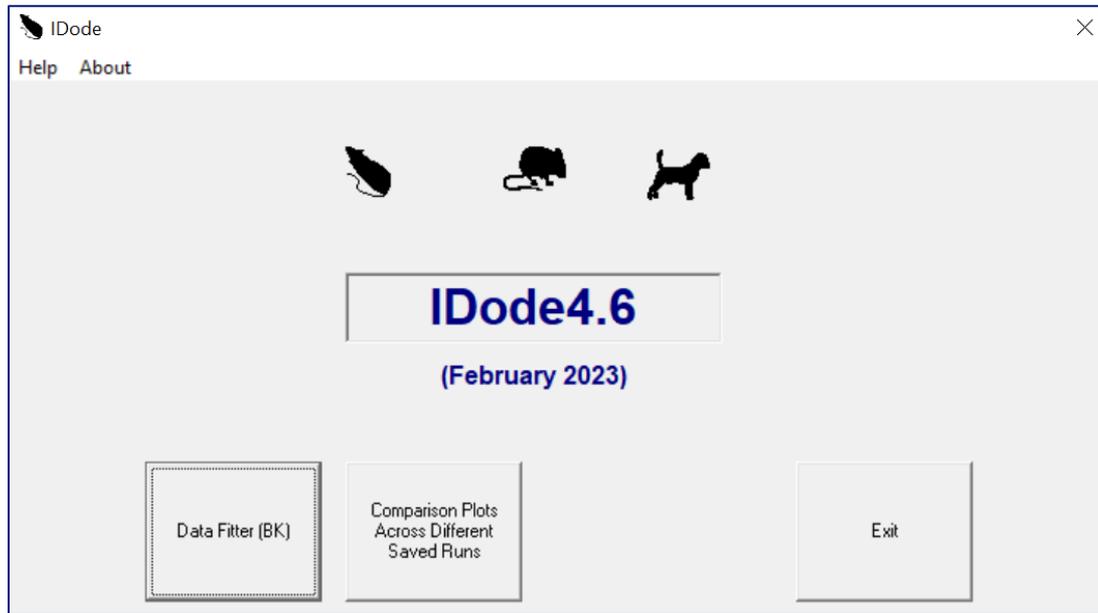
[Author Information](#) ⓘ

Health Physics: December 2020 - Volume 119 - Issue 6 - p 715-732

doi: 10.1097/HP.0000000000001282

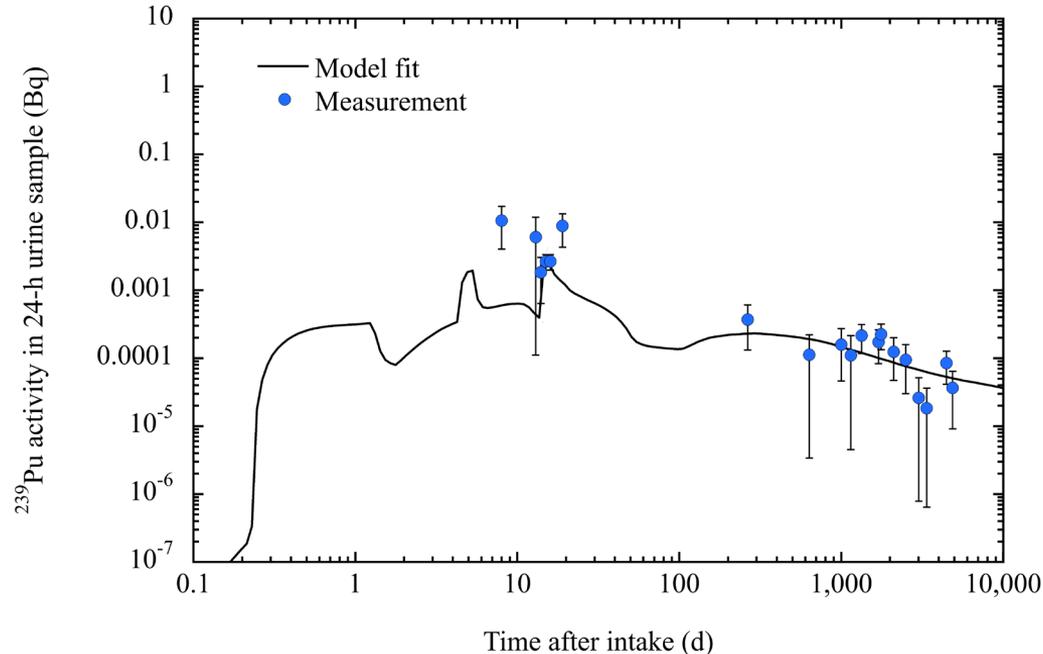
# Software Used

- IDode Software (*Miller et al. 2012*) was used for all calculations performed



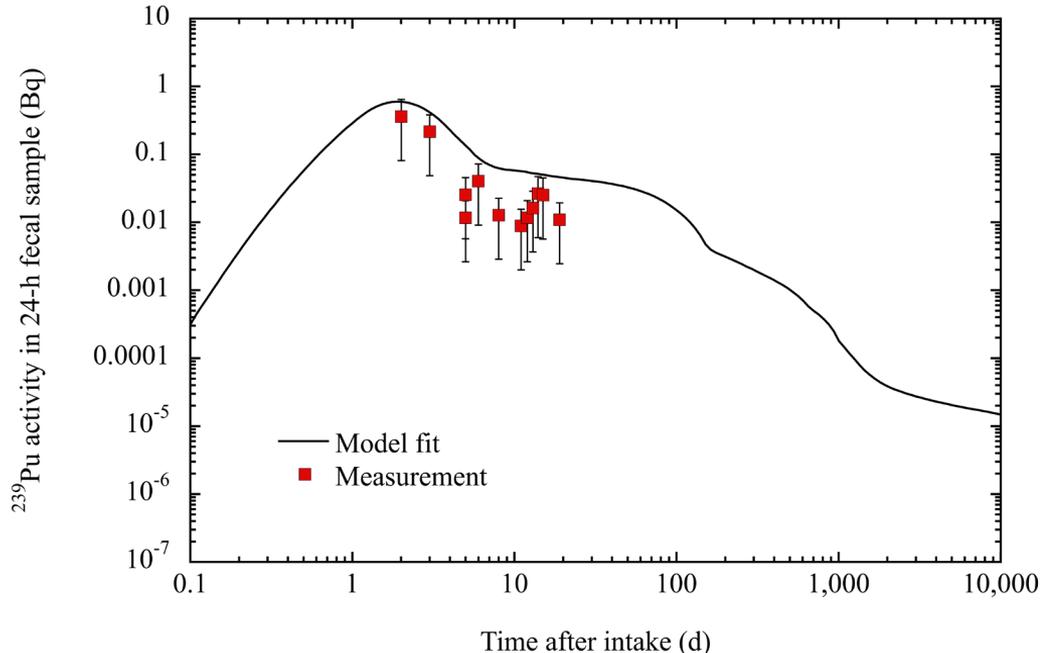
# Modeling of the Bioassay Data: Urine

- Fit to the combined  $^{239}\text{Pu}$  data in urine
  - A  $\chi^2/\text{nData}$  of  $\approx 1$  (0.95) for the entire dataset, 32 nData, was obtained during a simultaneous 4-parameter fit



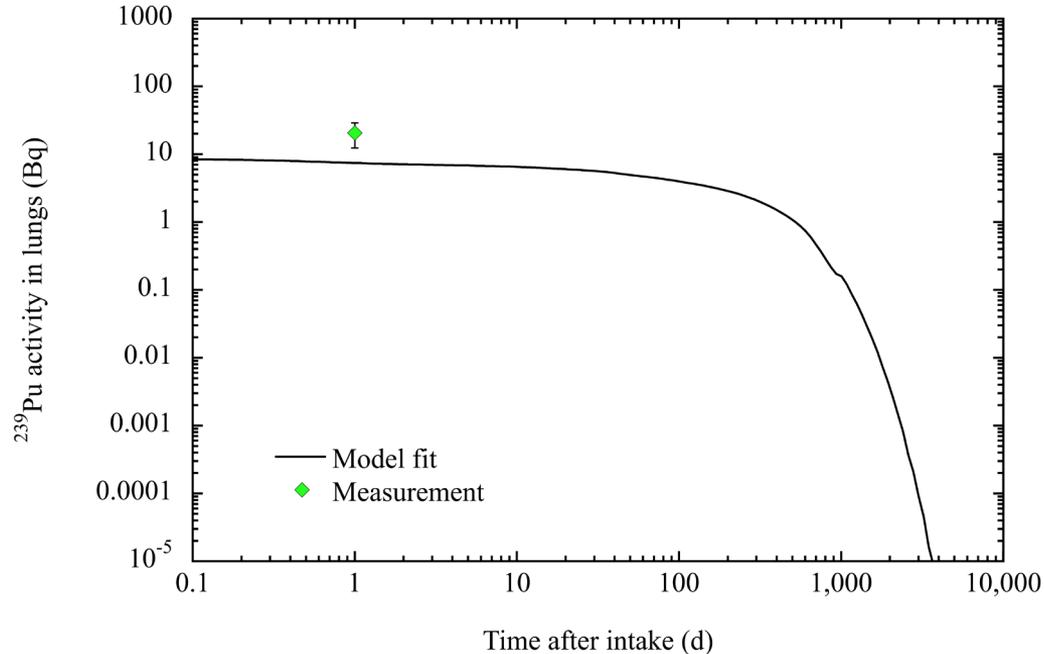
# Modeling of the Bioassay Data: Feces

- Fit to the combined  $^{239}\text{Pu}$  data in feces
  - A  $\chi^2/\text{nData}$  of  $\approx 1$  (0.95) for the entire dataset, 32 nData, was obtained during a simultaneous 4-parameter fit



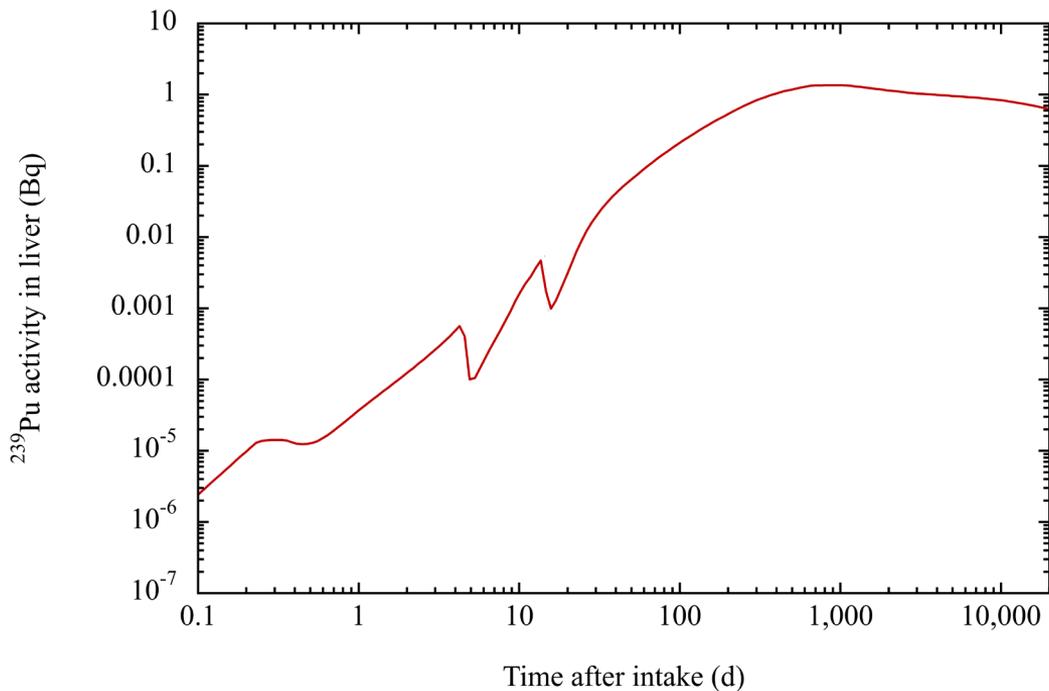
# Modeling of the Bioassay Data: Lungs

- Fit to the combined  $^{239}\text{Pu}$  data in lungs
  - A  $\chi^2/\text{nData}$  of  $\approx 1$  (0.95) for the entire dataset, 32 nData, was obtained during a simultaneous 4-parameter fit



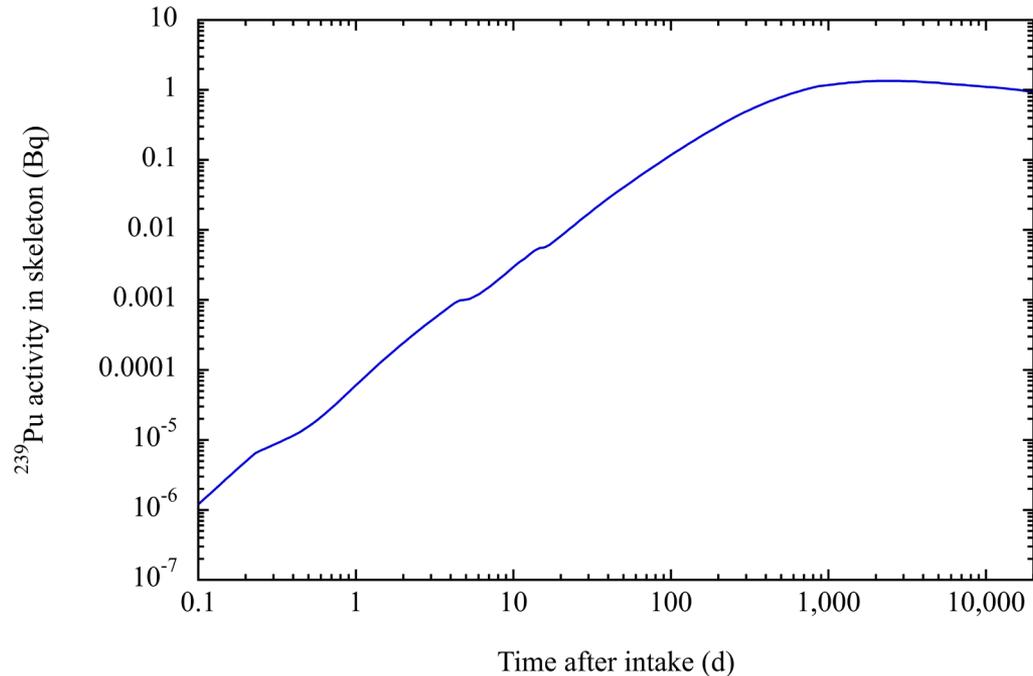
# Model Predictions of Liver Content

- Model Predictions of liver content throughout the years
- Chelation clearly observed in the liver



# Model Predictions of Skeleton Content

- Model Predictions of skeleton throughout the years
- Chelation slightly observed in the skeleton



# Intake Estimation

- The health physics evaluation conducted by her employer at the time of exposure indicated that the inhaled material contained 73.3 Bq of  $^{239}\text{Pu}$  (*Russell et al. 2003*)
- Preliminary results of the modeling in the present work showed an estimated intake of 21.6 Bq
  - In this work we use a smaller activity median aerodynamic diameter (AMAD) value (0.1 $\mu\text{m}$ )

Russell et al. Radiation Protection Dosimetry 104(3):231-236; 2003

# Limitations of the Study

- This study shows preliminary results
- Five urine data points were excluded because they were not 24 h collection and had conflicting “spot sample collections”, and one fecal data point was excluded because it had conflicting collecting period (timing not carefully described)
- Original chelation model was developed for intravenous Ca-DTPA, this study uses intramuscular Ca-DTPA

# Next Steps

- Finalize the fitting of the model into this dataset
- Perform dose assessment calculations
  - Markov Chain Monte Carlo (MCMC) calculations using IDode Software

# Summary

- This work shows the applicability of a unique USTUR dataset for biokinetic modeling studies, with focus on chelation modeling
  - Female nuclear worker treated with chelation therapy after plutonium exposure
- The importance of having early and long-term bioassay data
  - Not only urine data, but also including fecal data in the modeling (which is uncommon to find in the literature)
- Further modeling work will continue to be made, and also internal dose assessment calculations
- We aim to publish a paper in the Health Physics literature showing final results

# Thank You!

# Questions?