Biokinetic modeling using data from the U.S. Transuranium and Uranium Registries

Example: chelation therapy of USTUR Case 0846

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Karlsruhe Institute of Technology

"Learning from Plutonium and Uranium Workers"

Outline

- Who is presenting?
  - Karlsruhe Institute of Technology
  - EURADOS e.V.
- Why biokinetic modeling ?
- USTUR – The US Transuranium and Uranium Registries
- Example: Case 0846

Who is presenting?

PD Dr. Bastian Breustedt

Education

- University of Cologne
  - 2002: Diploma Physics
  - 2005: PhD – Monte Carlo Calibration of Whole Body Counter
- Karlsruhe Institute of Technology
  - 2012: Habilitation (venia legendi) – Radiation Protection

Work

- Since 2005 Karlsruhe Institute of Technology
  - 2005 – 2008: PostDoc – Biokinetic Modeling
  - Since 2007: Head of in-vivo monitoring laboratory of KIT
  - Since 2013: Head of Radioanalytical laboratories
- EURADOS e.V.
  - Member of WG7 "internal dosimetry" since 2007
  - Chairman of WG7 since 2018

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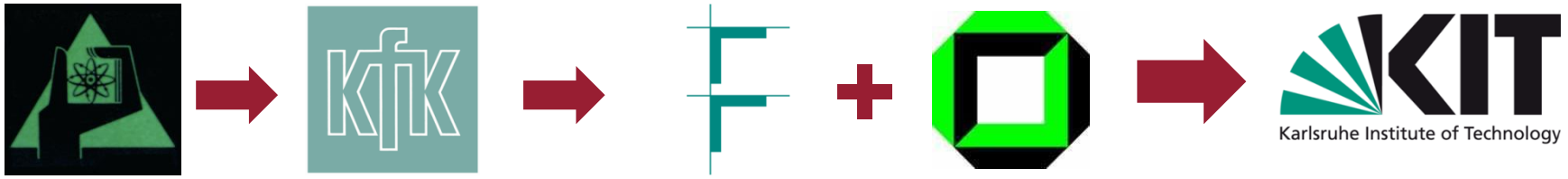
Work

2011: Visiting Scientist at
The US Transuranium and Uranium Registries (USTUR),
Richland, WA

Karlsruhe Institute of Technology - KIT

- Founded in 2009 as merger of
  - the former Research Centre Karlsruhe and
  - the Technical University of Karlsruhe



- Mission of a state university with research and teaching

- Mission of a research institution of the Helmholtz Association with program oriented provident research

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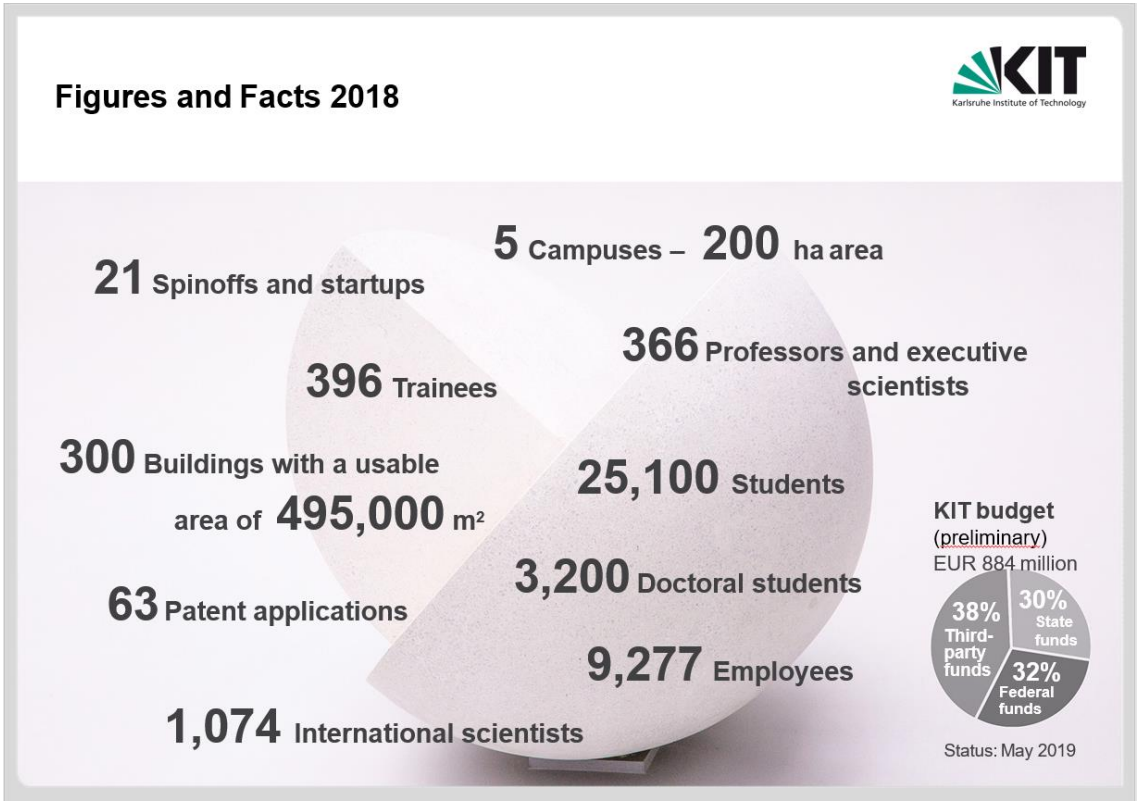


Radioanalytical Laboratories at KIT

- Quantification of radionuclides in samples and persons
  - Chemical Analytics
  - Physical Measurements
  - In-vivo Monitoring Laboratory



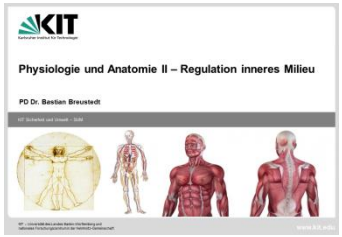
- Providing Service for internal and external customers
  - Accreditation on ISO 17025

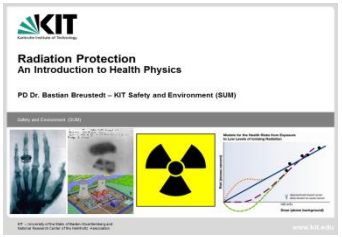
ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-11068-03-01

- Education and Training
  - Lectures at university part of KIT
  - Teaching and research projects

KVSF Kompetenzverbund Strahlenforschung

EURADOS

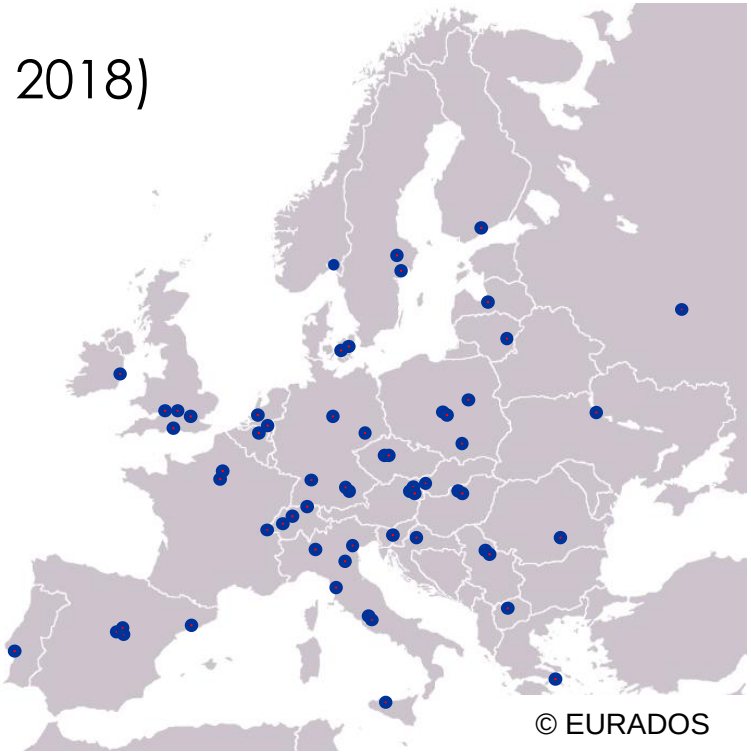




EURADOS e.V.

European Radiation Dosimetry Group e.V.

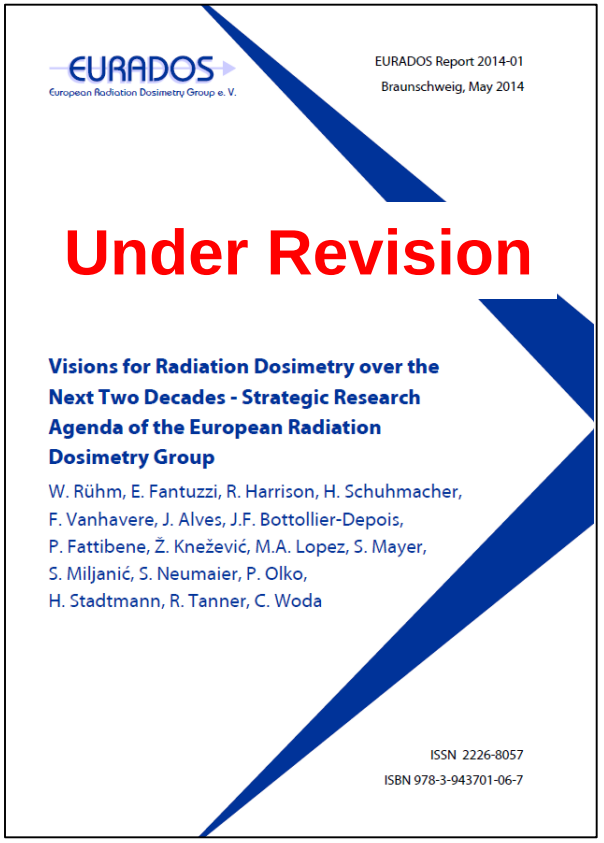
- http://www.eurados.org
- Mission since foundation in 1982
  - Promote research and development in dosimetry
  - Contribute to harmonisation in dosimetric practice
- Institutional Voting Members (June 2018)
  - 72 Voting Members from 30 countries
- Associate Members
  - Almost 500 scientists contributing to the overall EURADOS mission
- EURADOS Council
- EURADOS Office
  - operated by HMGU, Germany



EURADOS e.V.

European Radiation Dosimetry Group e.V.

- Strategic Research Agenda
  - Vision 1 – Towards updated fundamental dose concepts and quantities
  - Vision 2 – Towards improved radiation risk estimates deduced from epidemiological cohorts
  - Vision 3 – Towards an efficient dose assessment for radiological emergencies
  - Vision 4 – Towards integrated personalized dosimetry in medical applications
  - Vision 5 – Towards improved radiation protection of workers and the public



EURADOS e.V.

European Radiation Dosimetry Group e.V.

- EURADOS Working Groups
  - Harmonization of Individual Monitoring (P. Gilvin, UK)
  - Environmental Dosimetry (A. Vargas, Spain)
  - Computational Dosimetry (H. Rabus, Germany)
  - Internal Dosimetry (B. Breustedt, Germany)
  - Radiation Dosimetry in Radiotherapy (L. Stolarczyk, Poland)
  - Retrospective Dosimetry (L. Ainsbury, UK)
  - High-Energy Radiation Fields (M. Caresana, Italy)
  - Dosimetry in Medical Imaging (Z. Knezevic, Croatia)

EURADOS e.V.

European Radiation Dosimetry Group e.V.

- EURADOS Working Group 7 – Internal Dosimetry

" EURADOS WG7 acts as a **network** of

- Scientists,
- Services,
- Regulators and
- Laboratories

collaborating for the coordination of research and the dissemination of knowledge **for the assessment of doses due to intakes of radionuclides**."

END
of
Commercial Break

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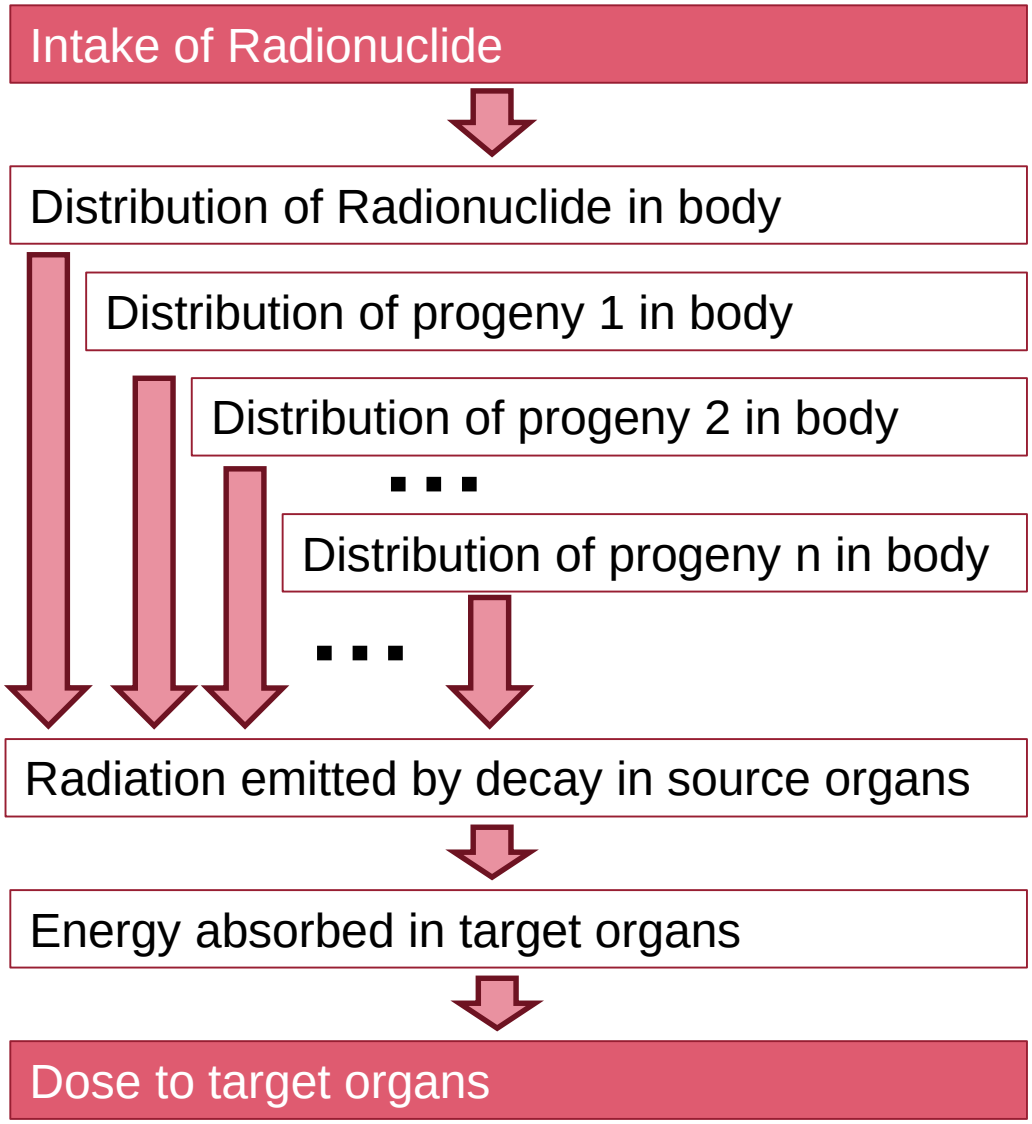
Why biokinetic modeling?

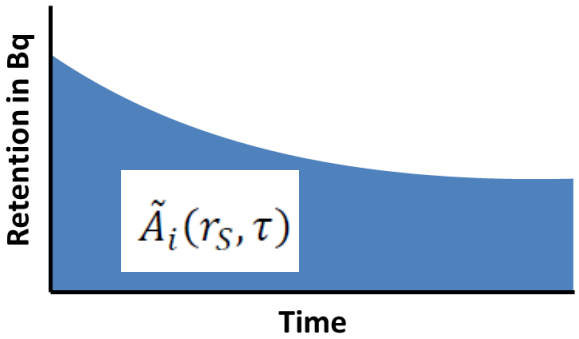


Why biokinetic modeling?

Intake of Radionuclide

↓

Distribution of Radionuclide in body



Biokinetic Model

$$\tilde{A}_i(r_S, \tau)$$

Radiation emitted by decay in source organs

↓

Energy absorbed in target organs

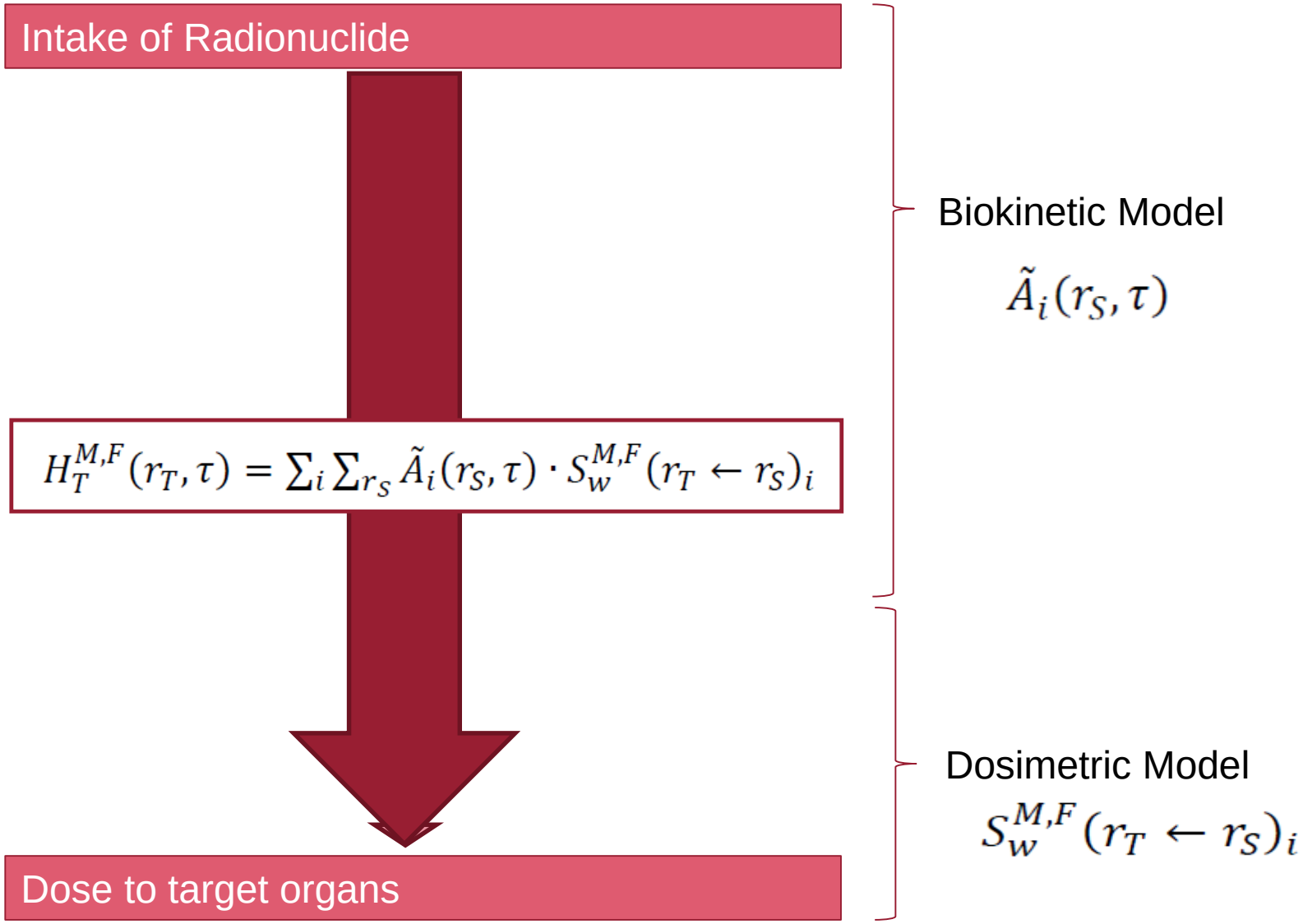
↓

Dose to target organs

Dosimetric Model

$$S_w^{M,F}(r_T \leftarrow r_S)_i$$

Why biokinetic modeling?



Why biokinetic modeling?

Intake of Radionuclide

Dose Coefficient:

Dose to target organ per Bq Intake

$$h_T{}^{M,F}(r_T,\tau) = \sum_i \sum_{r_S} \tilde{a}_i(r_S,\tau) \cdot S_w{}^{M,F}(r_T \leftarrow r_S)_i$$

Dose:

Intake * Dose Coefficient

$$H_T{}^{M,F}(r_T,\tau) = I \cdot h_T{}^{M,F}(r_T,\tau)$$

Dose to target organs

Biokinetic Model

$$\tilde{A}_i(r_S,\tau)$$

Proportional to Intake I

$$\tilde{A}(r_s,\tau) = I \cdot \tilde{a}(r_S,\tau)$$

Dosimetric Model

$$S_w^{M,F}(r_T \leftarrow r_S)_i$$

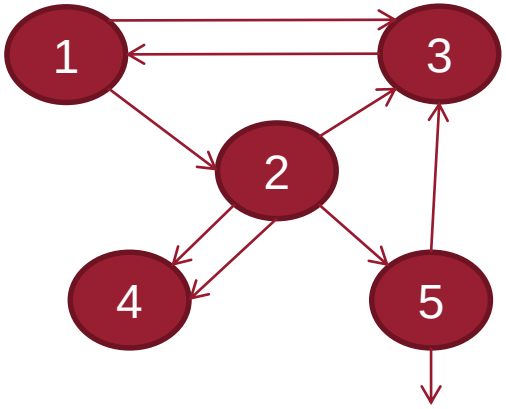
Why biokinetic modeling?

- Aim: Description of behavior of radionuclides inside the human body **for the use in internal dosimetry**
  - Intake into body
  - Distribution inside the body
  - Retention in organs and excretion from body
  - Models describe the behavior of stable isotopes of an element
    - radioactive decay included in models as additional kinetic (loss)
- Type of models: Compartmental models

  → Systems of differential equations
- Applications:
  - Interpretation of measurements in individual monitoring
    - Which activity has been incorporated to yield the measurement result of today?
    - Big question: When did the intake happen?
  - How many nuclear transformation happened in a given (source) organ?
    - Where is the radiation released and how much of it?
    - Integration period needs to be defined (e.g. 50 or 70 years)

Why biokinetic modeling?

- Aim: Description of behavior of radionuclides inside the human body **for the use in internal dosimetry**
- Development of biokinetic models – Workflow
  - Definition of **model structure**
    - Identification of tissues and pathways of transport
    - Physiological knowledge/assumptions, observed behaviour
  - System of Balance-Equations
  - Definition of **model parameters (for stable isotopes!)**
    - Quantification of transfers
    - Data required for fitting, decay correction



$$\Rightarrow \frac{d\vec{q}}{dt} = \bar{f} \cdot \vec{q} + \vec{I}$$

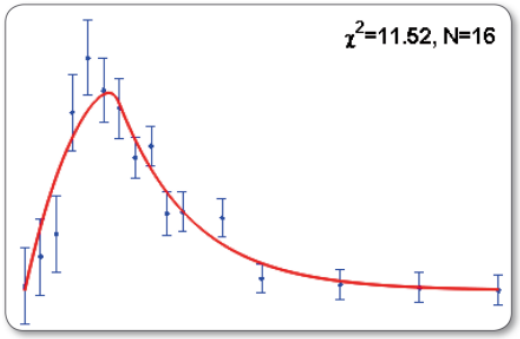


Image Source: https://en.wikipedia.org/wiki/PottersWheel, accessed 14.07.2016

Why biokinetic modeling?

- Aim: Description of behavior of radionuclides inside the human body **for the use in internal dosimetry**
- Data used for development of models
  - **H1**: direct information on humans, i.e. quantitative measurements of the element in human subjects;
  - **H2**: observations of the behaviour of chemically similar elements in human subjects;
  - **A1**: observations of the behaviour of the element in non-human species;
  - **A2**: observations of the behaviour of chemically similar elements in non-human species.
  - **P**: physiological data

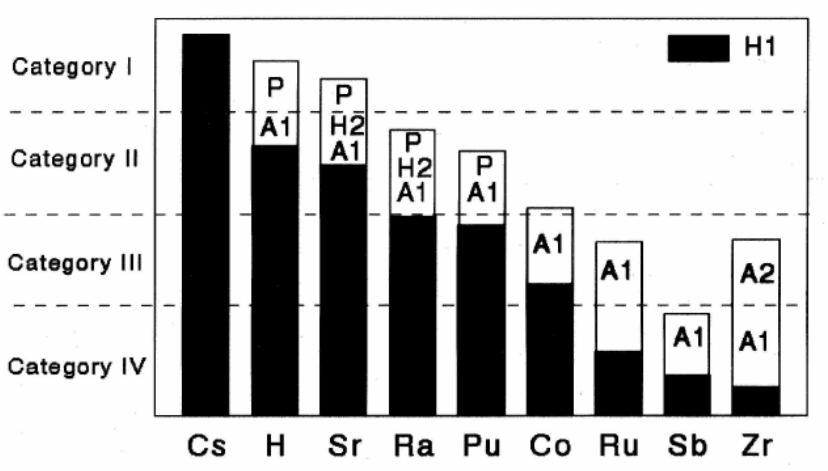


Image Source: Leggett, R.W.et al: Radiat. Prot. Dosim. **79**, 335-342 (1998).

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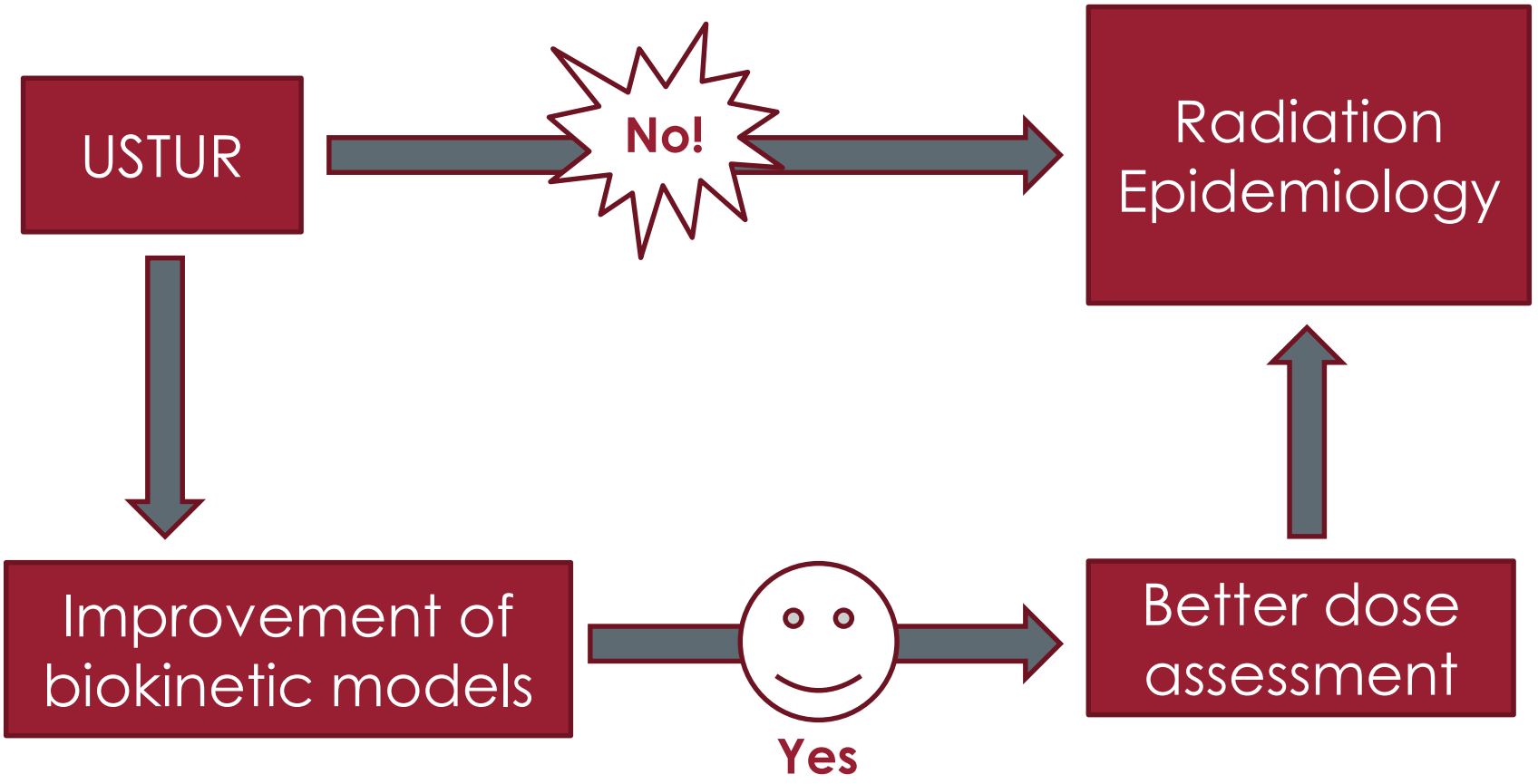
Disclaimer

United States Transuranium and Uranium Registries (USTUR):

- is not an epidemiological study
- focuses on actinide biokinetics for radiation protection and dosimetry
- supports radiation epidemiology through the improvement of biokinetic models for more accurate dose assessment

USTUR and Epidemiology: *Relationship*



USTUR Mission Statement

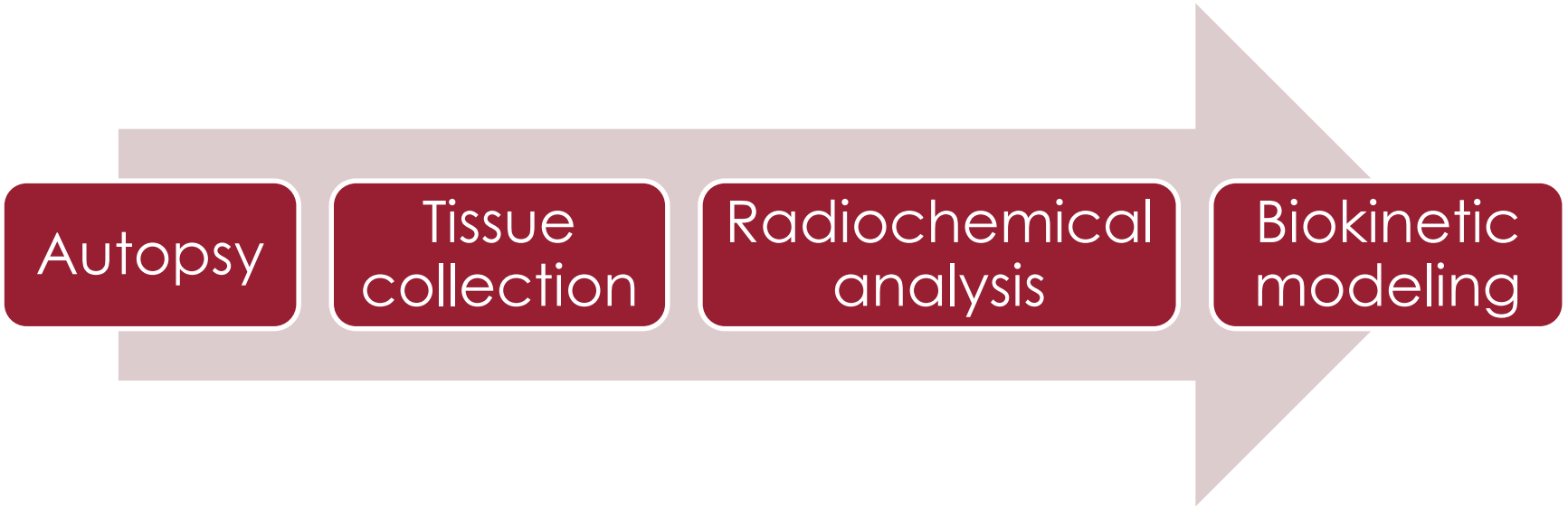
- Follow up occupationally-exposed individuals (volunteer Registrants) by studying the biokinetics (deposition, translocation, retention, and excretion) and tissue dosimetry of uranium and transuranium elements, such as plutonium, americium, curium, and neptunium
- Obtain, analyze, preserve, and make available for future research, tissues from individuals who had documented intakes of uranium and transuranium elements
- Apply USTUR data to refine dose assessment methods in support of reliable epidemiological studies, radiation risk assessment, and regulatory standards for radiological protection of workers and general public

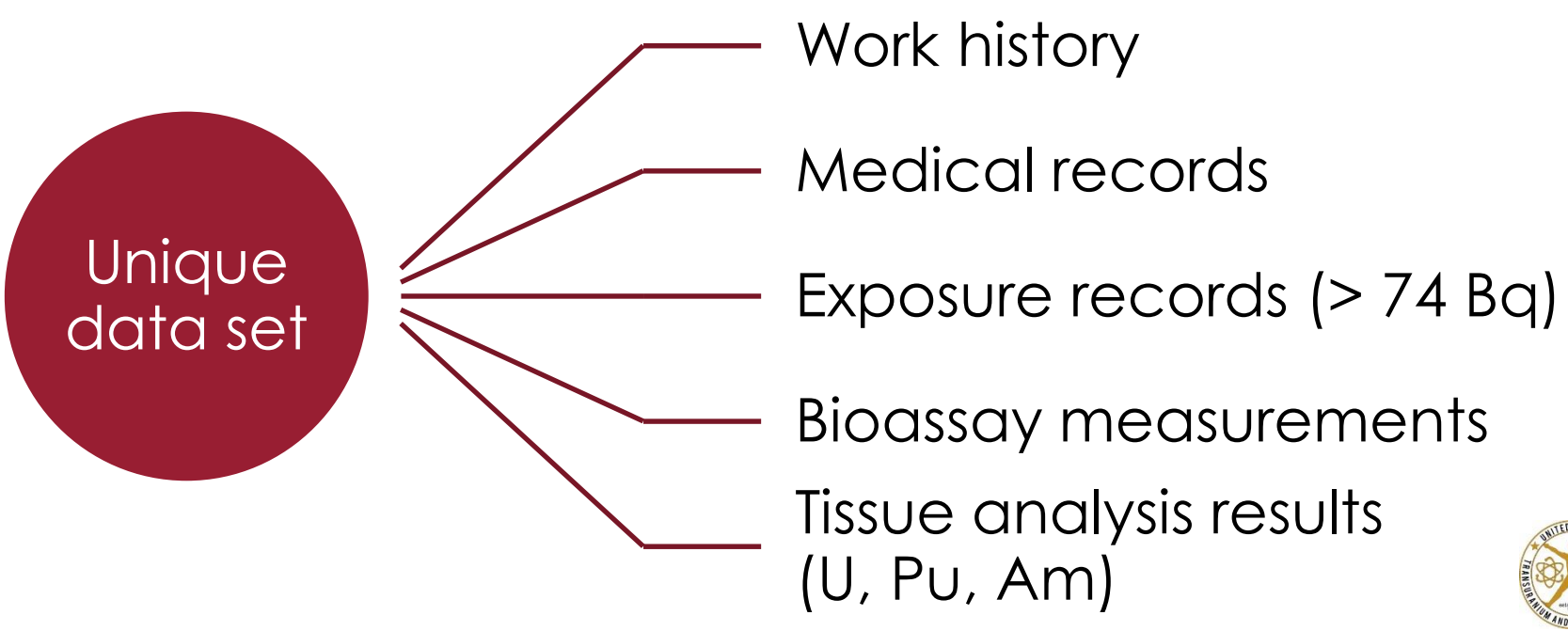
USTUR: Federal-grant program

- Funded by the U.S. Department of Energy (DOE) Office of Domestic and International Health Studies (AU-13)
- Operated by College of Pharmacy and Pharmaceutical Sciences at Washington State University under Central DOE Institutional Review Boards (DOE000320)
- Faculty and staff:

- Location: Richland, Washington, USA
- Website: ustur.wsu.edu

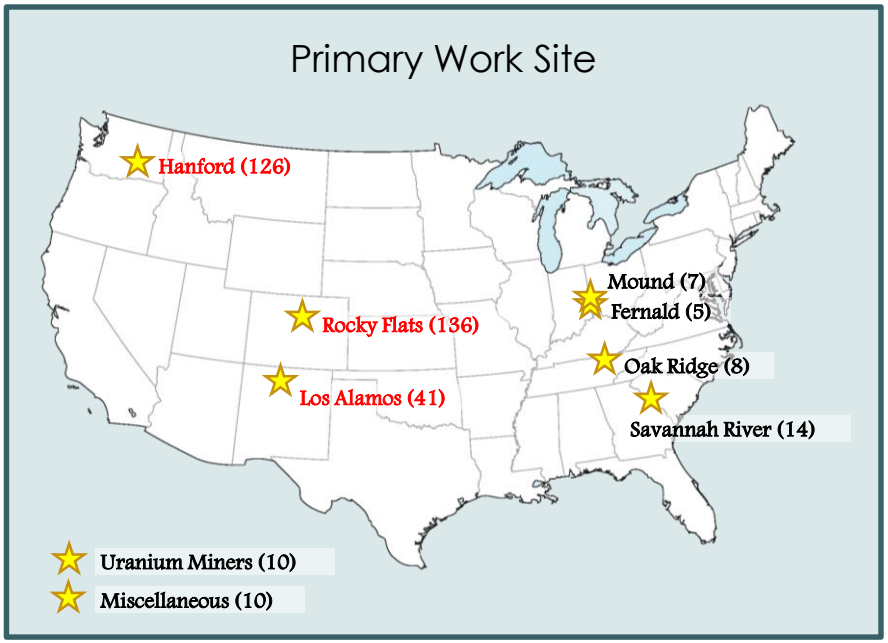
USTUR Operation and Research: *Schematic*





USTUR: Who are our donors?

357 Registrant Donations (volunteer tissue donor)



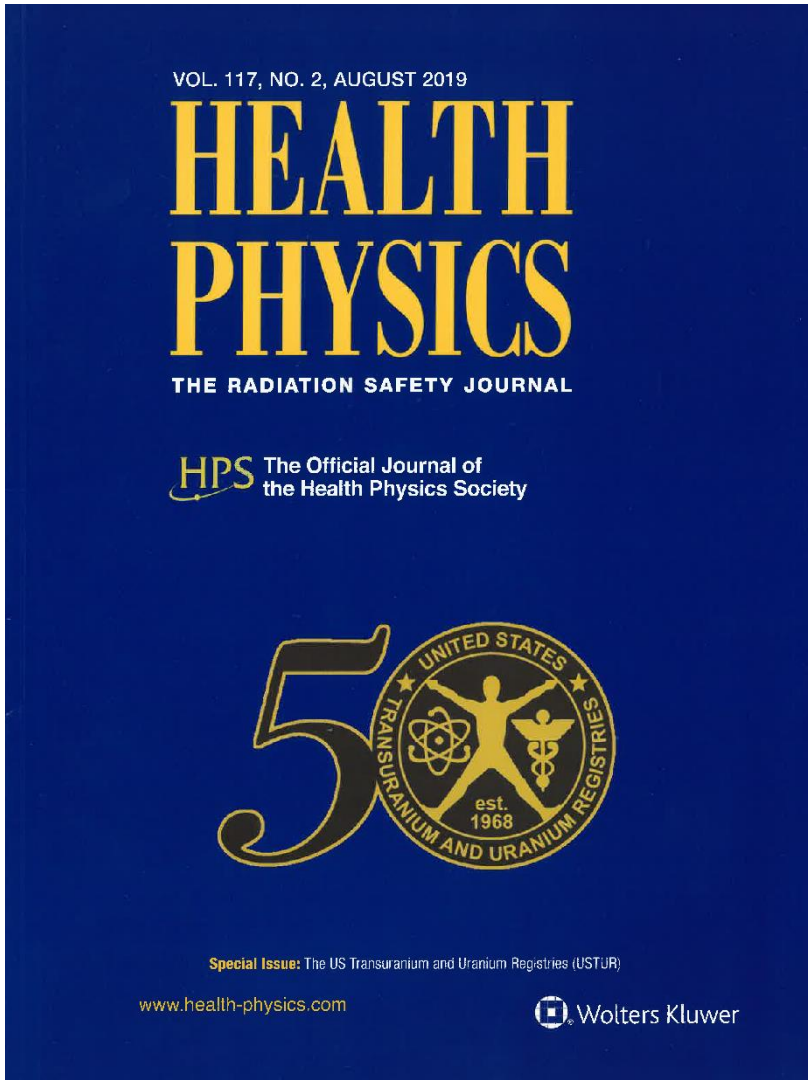
Male: 345
Female: 12

Ever- : 218 (61%)
Non- : 51 (14%)
Unknown: 88 (25%)

Age at death
69 ± 13 years

+31 Living Registrants (age: 82 ± 11 years)

USTUR 50th Anniversary: *Special Issue of Health Physics Journal*



Paper

THE US TRANSURANIUM AND URANIUM REGISTRIES (USTUR): A FIVE-DECADE FOLLOW-UP OF PLUTONIUM AND URANIUM WORKERS

Ronald L. Kathren and Sergei Y. Tolmachev[1]

Abstract—**Dedication: The research of the US Transuranium and Uranium Registries relies heavily upon postmortem autopsy findings and radiochemical analysis of tissues. The enormous debt owed to those now-deceased registrants who unselfishly voluntarily participated in the US Transuranium and Uranium Registries program through postmortem donation of their tissues and to those still-living registrants who have volunteered to be future postmortem tissue donors is hereby acknowledged with gratitude. The scientific findings derived from postmortem analysis of these tissues have been instrumental in advancing our understanding of the actinide elements in humans and have led to refinement, validation, and confidence in safety standards for those who work with these elements as well as for the general public. To these generous and anonymous persons who made this ultimate contribution, this paper is dedicated with great thanks and admiration.**
Health Phys. 117(2):118–132; 2019

Key words: biokinetics; plutonium; US Transuranium and Uranium Registries; uranium

INTRODUCTION

Realization of the hazards of plutonium

From the outset of the Manhattan Engineering District (MED), safety and in particular, radiological safety, have been important considerations. Although human experience with element 92 uranium, which is ubiquitous in nature, spanned centuries (the metal itself had been identified in 1789), the situation with element 94 was quite different. Element 94 was a new element, artificially created and "discovered" on 25 February 1941 and named plutonium (Hewlett and Anderson 1962; Kathren et al. 1994; Seaborg 1946). Because plutonium is not found in nature, there was no human experience with it, but vast quantities would be produced by the MED. Because of the similarities with radium, the necessity for biological study of both plutonium and uranium was quickly understood, spurred in large measure by the recent tragic experience of the radium dial painters. Historian Barton Hacker summed the plutonium problem up well, noting "everyone expected plutonium to be a major hazard" (Hacker 1987).

MED director General Leslie R. Groves noted in his memoir that the most urgent problem of the medical department was to determine the toxicity of uranium and plutonium (Groves 1962), and Glenn Seaborg, Nobel Prize-winning discoverer of plutonium, expressed concern about the potential health hazards of plutonium and the need for haste in studying them. Even before meaningful quantities of plutonium could be made, Seaborg, then in charge of MED plutonium chemistry research, wrote in a memo to Robert Stone, MED medical director:

> *"In addition to helping to set up safety measures in handling so as to prevent the occurrence of such accidents I would like to suggest that a program to trace the course of plutonium in the body be initiated as soon as possible. In my opinion, such a program should have the very highest priority."* (Memo, Seaborg to Stone dated 4 January 1944, reprinted in Kathren et al. 1994).

Accordingly, when the plutonium became available a month later, 11 mg (2.2% of the total amount then in existence) were sent to Joseph Hamilton for biological studies (Kathren et al. 1994).

First human studies with plutonium: the plutonium injection cases

The earliest human studies of plutonium, conducted at a time when ethical concerns were very much relaxed relative to today, were carried out primarily to resolve conflicting animal data, for extrapolation from animals, and for the development of appropriate biokinetic models and human safety limits on radionuclide intake. The scientific aspects of the initial studies have been well documented and sum

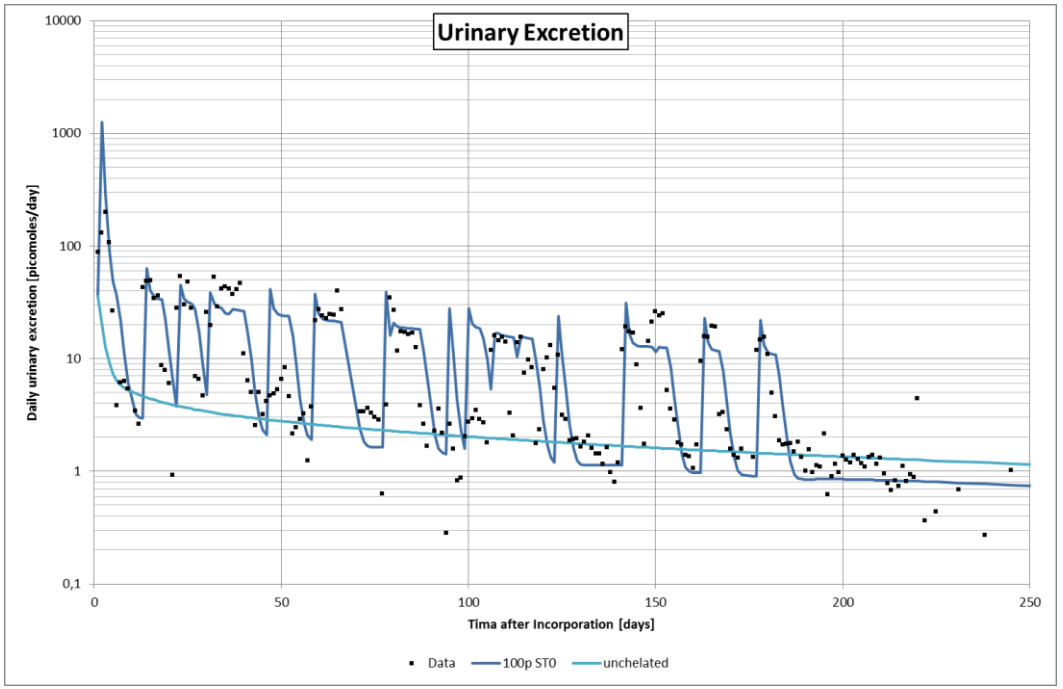
[1]US Transuranium and Uranium Registries, Washington State University, 1845 Terminal Drive, Suite 201, Richland, WA 99354.
The authors declare no conflicts of interest.
For correspondence contact Ronald L. Kathren, 137 Spring Street, Richland, WA 99354, or email at **kathren@bmi.net**.
(*Manuscript accepted* 30 July 2018)
0017-9078/19/0

DOI: 10.1097/HP.0000000000000963

Why using USTUR data for modeling (of chelation therapy) ?

- DTPA chelation therapy removes "accessible" ^{241}Am in extracellular fluids
  - ✓ How are extracellular fluids in ICRP models represented?

- Example (USTUR Case 0269)
  - ✓ ST0 compartment



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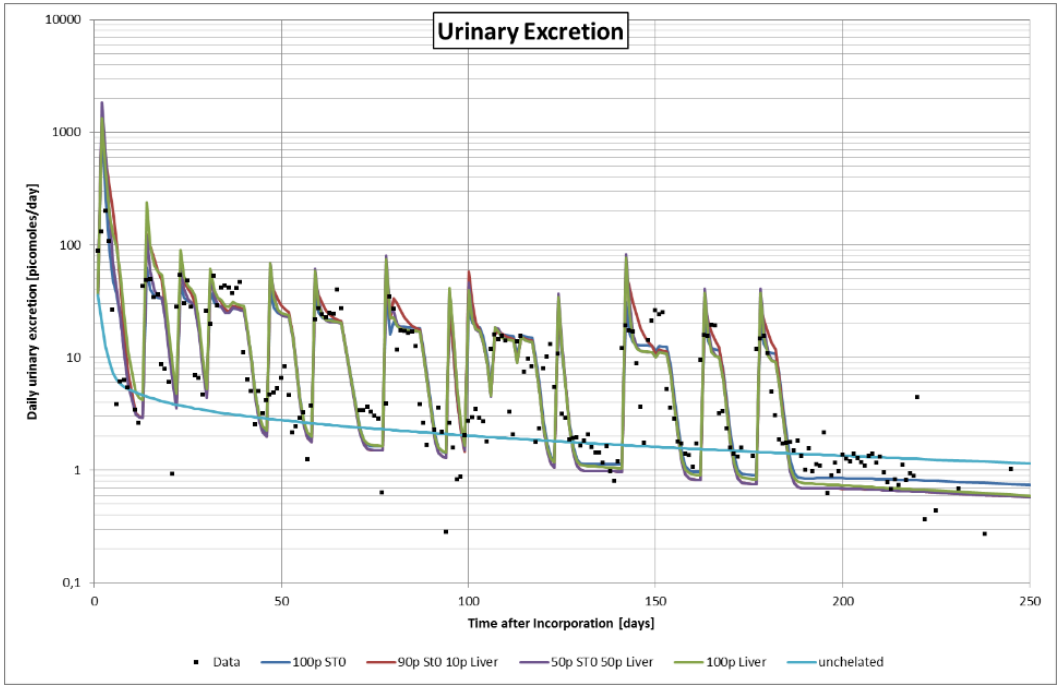
  - ✓ ST0 compartment
  - ✓ ST0 + liver (x %)
- Fit to urine data possible for several assumptions



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- Example (USTUR Case 0269)
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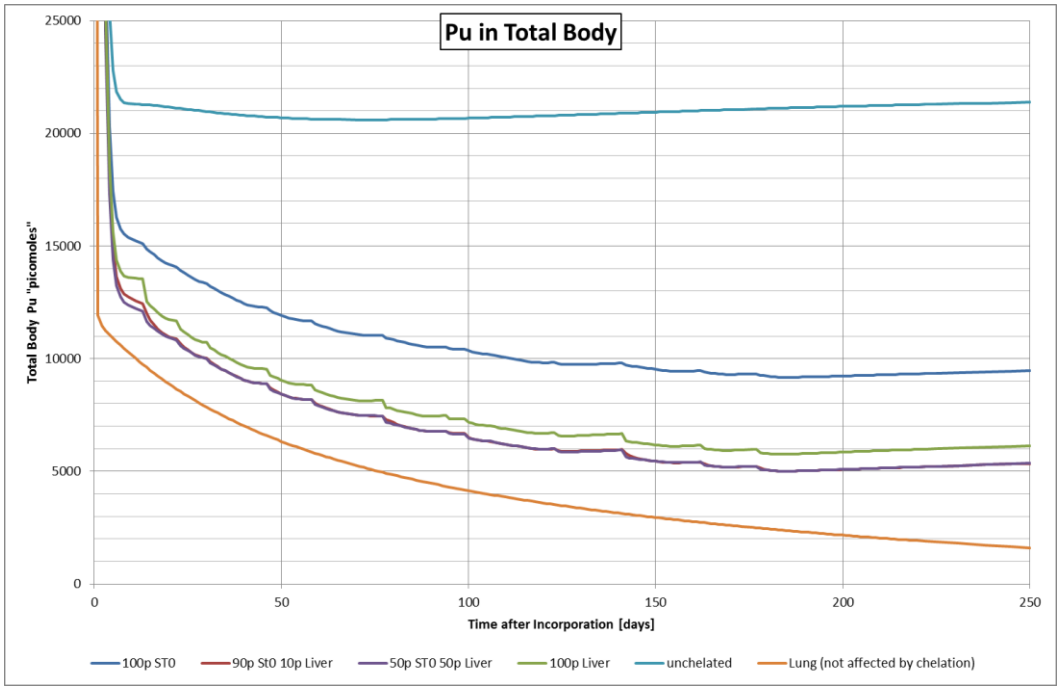
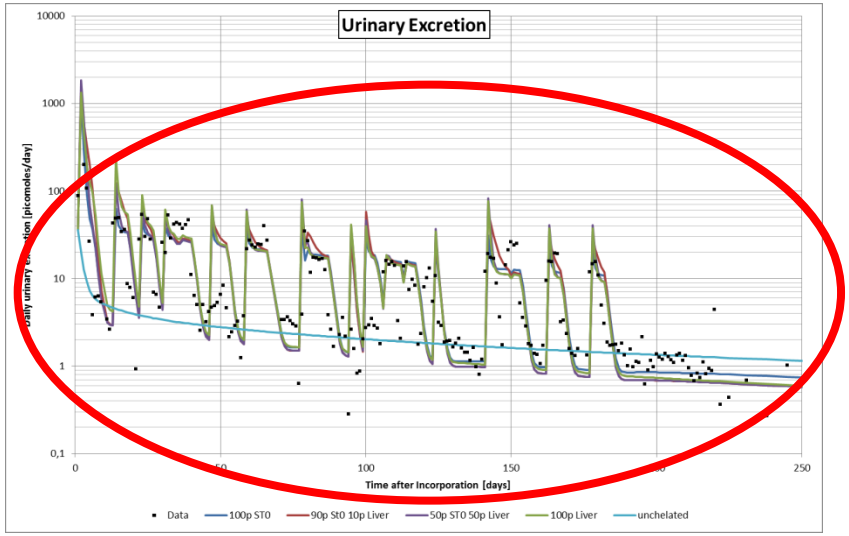
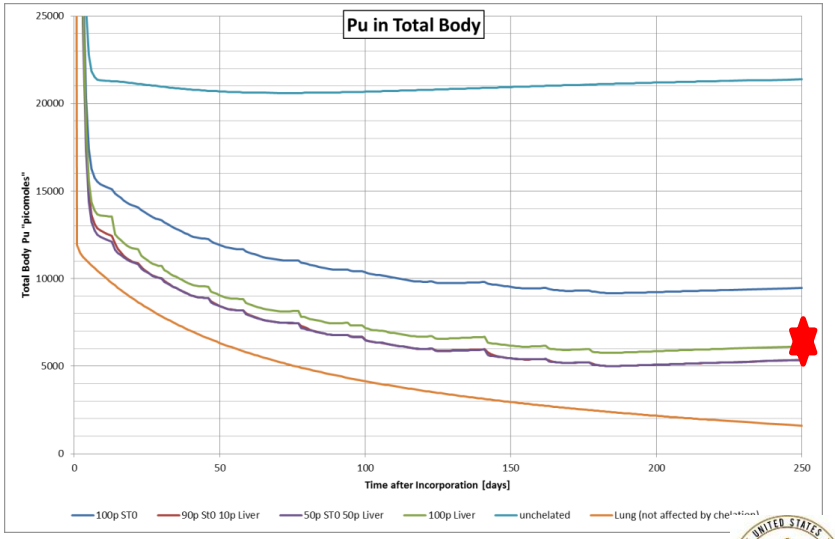
  - ✓ ST0 + liver (x %)
- Fit to urine data possible for several assumptions
- Different predictions of effect of therapy



Why using USTUR data for modeling (of chelation therapy) ?

- USTUR has a large collection of data of chelated cases
  - ✓ Health Physics Database
    - Urinary and Fecal excretion
    - In-vivo counting (mainly for ^{241}Am)
  - ✓ Autopsy data
    - Provides insight at distribution after therapy





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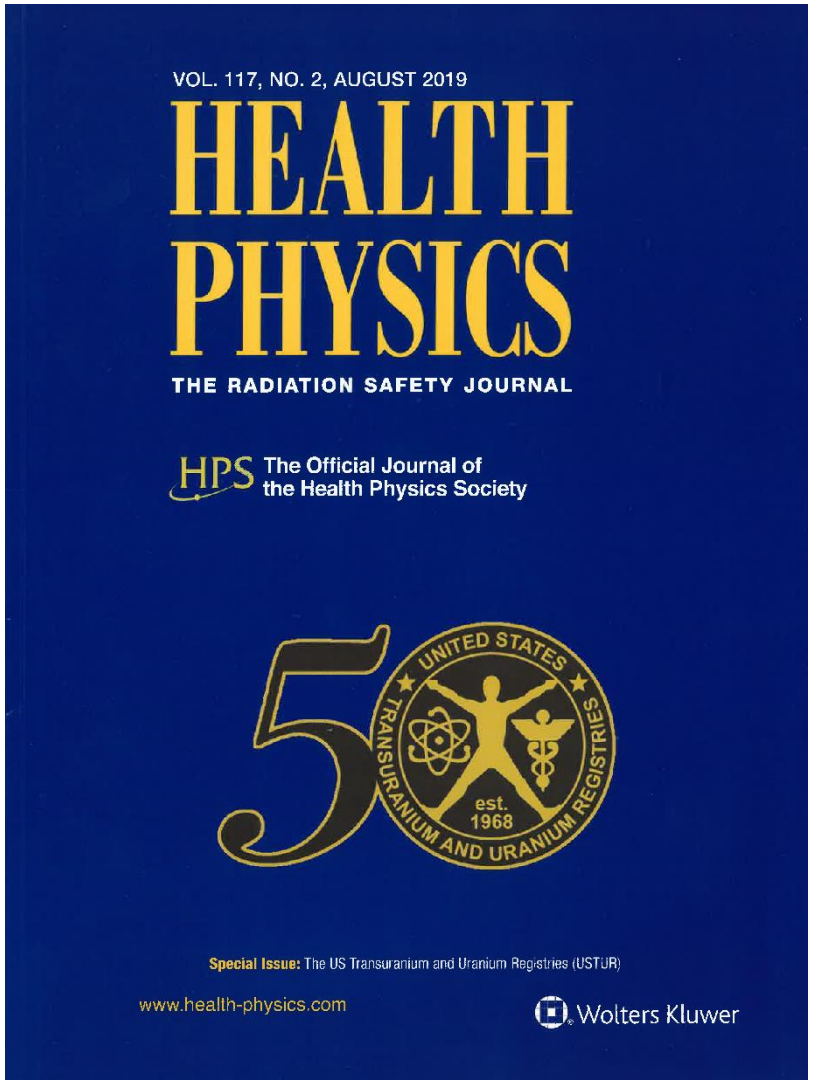
USTUR 50th Anniversary: *Special Issue of Health Physics Journal*



Paper

USTUR CASE 0846: MODELING AMERICIUM BIOKINETICS AFTER INTENSIVE DECORPORATION THERAPY

Bastian Breustedt,[1] Maia Avtandilashvili,[2] Stacey L. McComish,[2] and Sergei Y. Tolmachev[2]

Abstract—**Decorporation therapy with salts of diethylenetriamine-pentaacetic acid binds actinides, thereby limiting uptake to organs and enhancing the rate at which actinides are excreted in urine. International Commission on Radiological Protection reference biokinetic models cannot be used to fit this enhanced exertion simultaneously with the baseline actinide excretion rate that is observed prior to the start of therapy and/or after the effects of therapy have ceased. In this study, the Coordinated Network on Radiation Dosimetry approach, which was initially developed for modeling decorporation of plutonium, was applied to model decorporation of americium using data from a former radiation worker who agreed to donate his body to the US Transuranium and Uranium Registries for research. This individual was exposed to airborne ^{241}Am, resulting in a total-body activity of 66.6 kBq. He was treated with calcium-diethylenetriamine-pentaacetic acid for 7 y. The time and duration of intakes are unknown as no incident reports are available. Modeling of different assumptions showed that an acute intake of 5-µm activity median aerodynamic diameter type M aerosols provides the most reasonable description of the available pretherapeutic data; however, the observed ^{241}Am activity in the lungs at the time of death was higher than the one predicted for type M material. The Coordinated Network on Radiation Dosimetry approach for decorporation modeling was used to model the in vivo chelation process directly. It was found that the Coordinated Network on Radiation Dosimetry approach, which only considered chelation in blood and extracellular fluids, underestimated the urinary excretion of ^{241}Am during diethylenetriamine-pentaacetic acid treatment; therefore, the approach was extended to include chelation in the liver. Both urinary excretion and whole-body retention could be described when it was assumed that 25% of chelation occurred in the liver, 75% occurred in the blood and ST0 compartment, and the chelation rate constant was 1×10^{-10} pmol^{-1} d^{-1}. It was observed that enhancement of urinary excretion of ^{241}Am after injection of diethylenetriamine-pentaacetic acid exponentially decreased to the baseline level with an average half-time of 2.2 ± 0.7 d.**

[1]Karlsruhe Institute of Technology, Safety and Environment (SUM), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany; [2]US Transuranium and Uranium Registries, College of Pharmacy, Washington State University, 1845 Terminal Drive, Suite 201, Richland, WA 99354-4959.

The authors declare no conflicts of interest.

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(*Manuscript accepted* 1 *June* 2018)
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DOI: 10.1097/HP.0000000000000931

Health Phys. 117(2):168–178; 2019

Key words: ^{241}Am; biokinetics; Ca-DTPA; US Transuranium and Uranium Registries

INTRODUCTION

One technique for reducing the committed dose resulting from significant intakes of actinides is decorporation therapy based on intravenous injections of trisodium calcium and/or zinc diethylenetriamine-pentaacetic acid (DTPA). This chelating agent forms stable complexes with actinides, which are rapidly excreted. On the first day after the therapy, the excretion of actinides in urine is enhanced. In the following days, the observed urinary excretion rates return to the baseline excretion rate that would be expected without this therapy. This enhanced excretion removes a fraction of the deposited activity from the body, thus reducing the committed dose.

Reference biokinetic models published by the International Commission on Radiological Protection (ICRP) with their default parameters (ICRP 1993, 1994, 1997) cannot be used to simultaneously fit the enhanced and baseline urinary excretion rates. Several approaches that account for the effect of decorporation therapy have been proposed (Breustedt et al. 2009; Fritsch et al. 2007; Hall et al. 1978; James et al. 2007; Konzen and Brey 2015). However, their predictions are strongly dependent on underlying assumptions, which vary considerably (e.g., the sites of chelation or availability of the actinide for chelation). In addition to the bioassay data, which can be fairly well described by all these models, tissues donated to the US Transuranium and Uranium Registries (USTUR) provide information on activities in major organs and tissues at the time of death, which can be compared with model predictions and used to refine the assumptions behind the modeling. The Coordinated Network on Radiation Dosimetry (CONRAD) approach (Lopez et al. 2008; Breustedt et al. 2009) was initially developed for modeling decorporation of plutonium from the blood and extracellular fluids. In this study the CONRAD approach was applied to describe ame

Case 0846 – Scenario

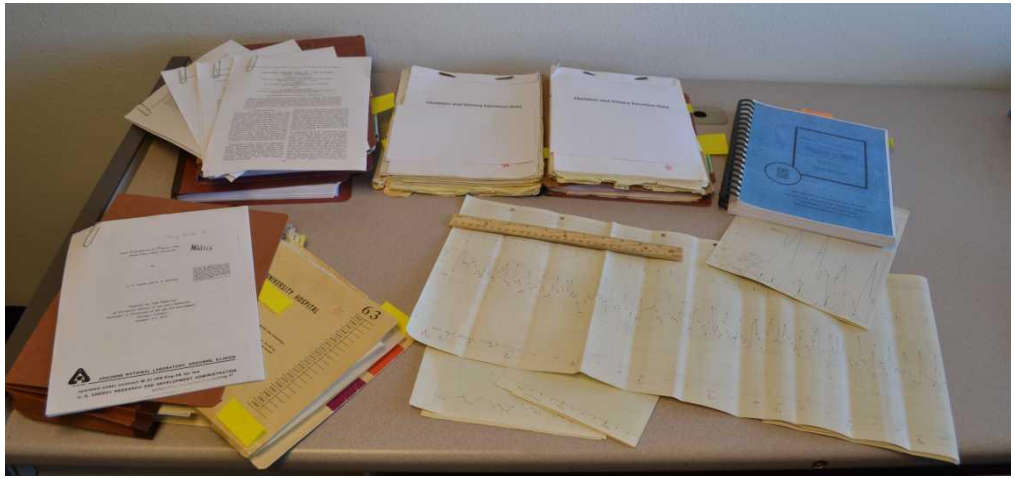
- Manufacturing sources containing $^{241}AmO_2$
  - ✓ 50 compacts manufactured over 3 years
- Compacting/pressing of pellet in pressing hood
  - ✓ Half-mask respirator worn for transfer and compacting
  - ✓ A "small" amount of visible dust was sometimes released during the pressing operation in the hood
- Alpha activity was detected in urine samples
  - ✓ Worker was sent to WBC
  - ✓ Estimated body burden = 1.8 mCi = 66,7 kBq (36 times the Maximum Permissible Body Burden)

Case 0846 – Therapy and Bioassay

- Removed from work and chelation therapy started
- 380 week therapy
  - ✓ total administration of 313.5g Ca-DTPA
    - 285 i.v. of 1g Ca-DTPA: once a week
    - 57 i.v. of 0.5g Ca-DTPA: twice per week
    - 43 weeks without treatment
- Extensive Bioassay Measurements under Treatment
  - ✓ Weekly body counts until week 60 of therapy
  - ✓ Fecal collection until week 80
  - ✓ Virtually all urine has been collected under therapy
    - Daily collection in the first two years of therapy
    - Weekly collection in the following 5 years
    - One week per month in the last year

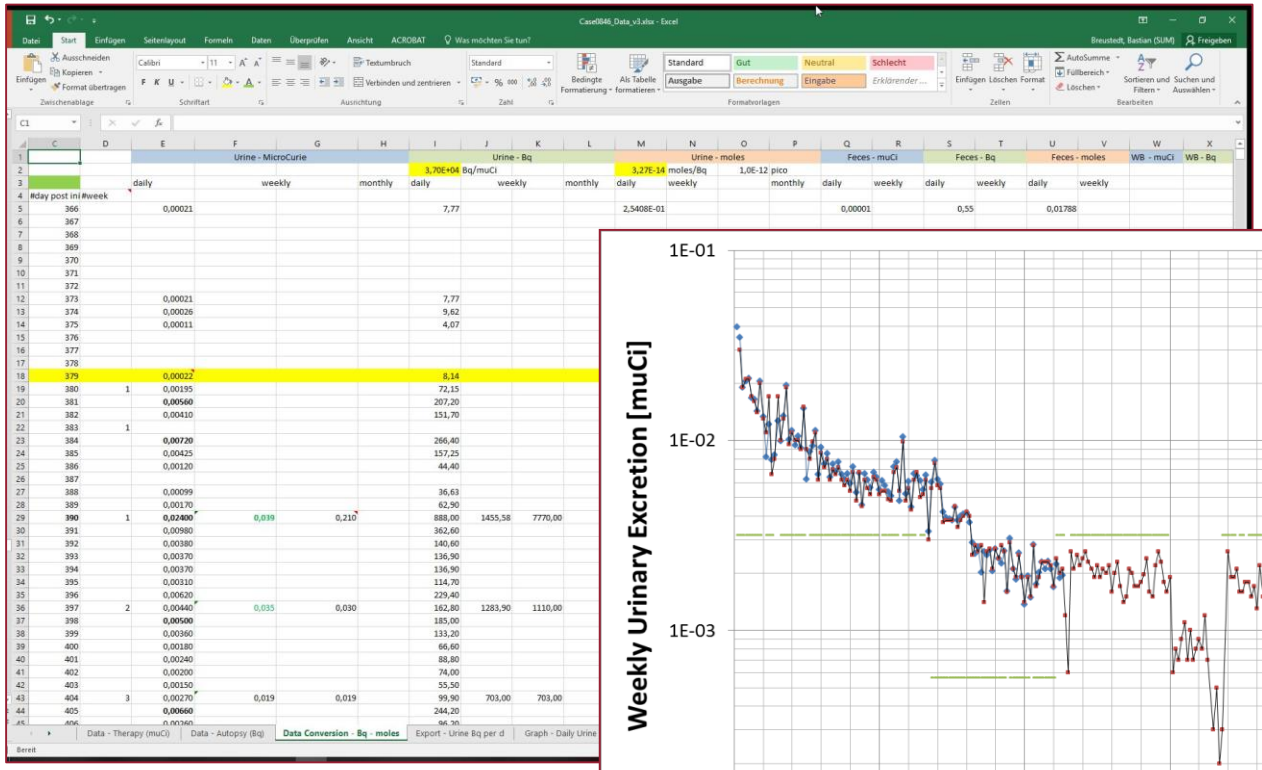
Case 0846 – Materials

- The case has been studied intensively (in 1960s - 1970s)
  - ✓ Several reports and papers in Health Physics Journal
  - ✓ Chapter in book for HPS Summer School 2004
- Bioassay data, exposure and medical records are available at USTUR



Case 0846 – The Dataset

- Data were collected and standardized in MS Excel file



	Urine - MicroCurie			Urine - Bq			Urine - moles			Feces - muCi		Feces - Bq		Feces - moles		WB - muCi	WB - Bq
				3,70E+04 Bq/muCi			3,27E-14 moles/Bq		1,0E-12 pico								
	daily		weekly	monthly	daily	weekly	monthly	daily	weekly	monthly	daily	weekly	daily	weekly	daily	weekly		
#day post ini	#week																	
366		0,00021			7,77			2,5408E-01			0,00001		0,55		0,01788			
367																		
368																		
369																		
370																		
371																		
372																		
373		0,00021			7,77													
374		0,00026			9,62													
375		0,00011			4,07													
376																		
377																		
378																		
379		0,00022			8,14													
380	1	0,00195			72,15													
381		**0,00560**			207,20													
382		0,00410			151,70													
383	1																	
384		**0,00720**			266,40													
385		0,00425			157,25													
386		0,00120			44,40													
387																		
388		0,00099			36,63													
389		0,00170			62,90													
390	1	**0,02400**	0,039	0,210	888,00	1455,58	7770,00											
391		0,00980			362,60													
392		0,00380			140,60													
393		0,00370			136,90													
394		0,00370			136,90													
395		0,00310			114,70													
396		0,00620			229,40													
397	2	0,00440	0,035	0,030	162,80	1283,90	1110,00											
398		**0,00500**			185,00													
399		0,00360			133,20													
400		0,00180			66,60													
401		0,00240			88,80													
402		0,00200			74,00													
403		0,00150			55,50													
404	3	0,00270	0,019	0,019	99,90	703,00	703,00											
405		**0,00660**			244,20													

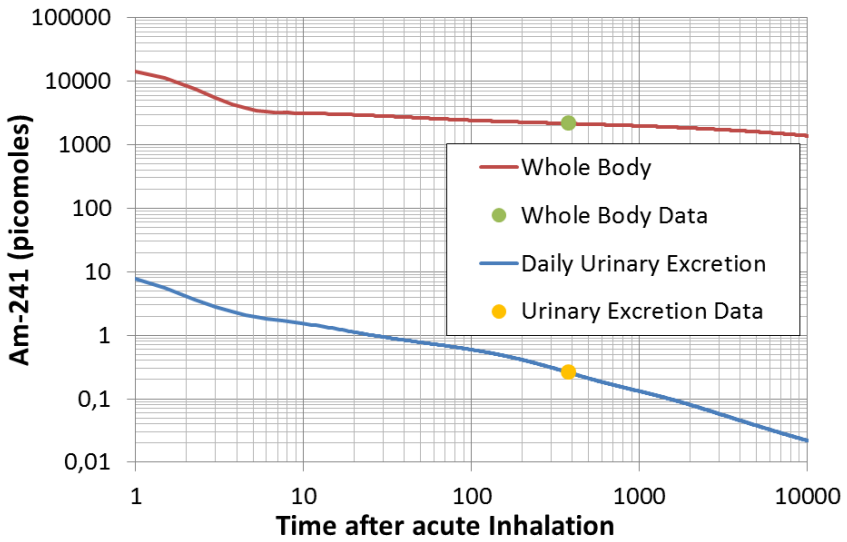
Case 0846 – Original Analysis

- Pre ICRP Publication 30 era
  - ✓ Empirical equations, no compartmental models
- Assumptions
  - ✓ average intake 2 years before therapy
  - ✓ "DTPA complexes americium and plutonium as soon as it leaves bone surfaces and transports the complex to urine for excretion"
- Conclusions
  - ✓ Half of the body burden removed is by action of DTPA
  - ✓ 7 years post therapy "the body burden was 0.72mCi with most of remaining burden in bones"

Quotes taken from: Allen Brodsky and Niel Wald @ HPS SummerSchool 2004

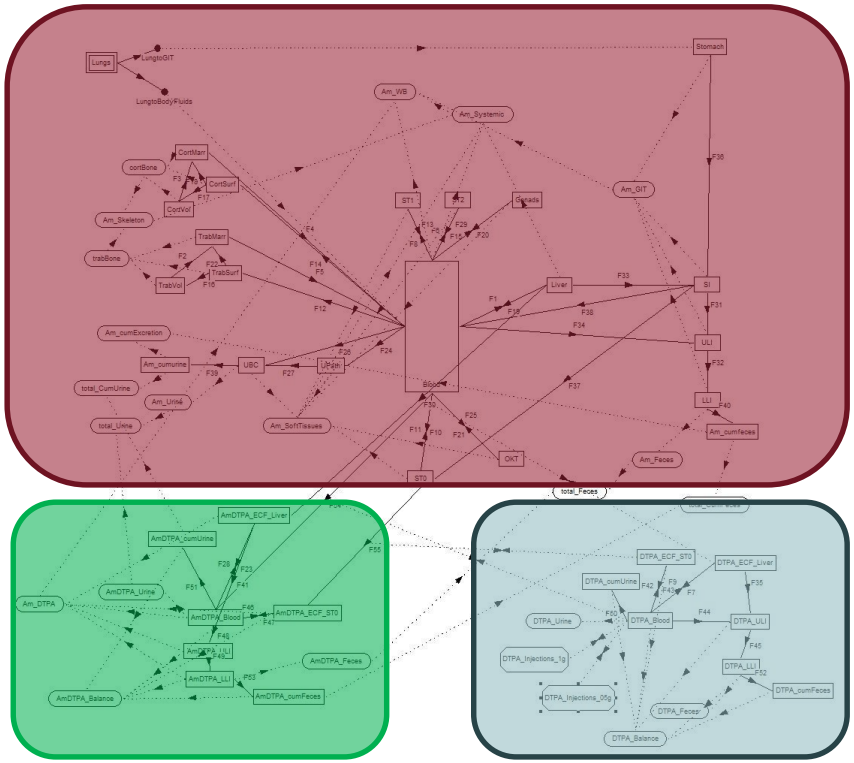
Case 0846 – New Analysis

- ICRP compartmental models and reference values
  - ✓ Lung (ICRP 66, Class M)
  - ✓ Americium systemic (ICRP 67)
  - ✓ GIT (ICRP30, f_1=0.005)
- Definition of initial scenario using pre-therapeutic data and information
  - ✓ Urine: 8.14 Bq/d
  - ✓ Whole body 66.7 kBq
- Acute intake
  - ✓ 1.2 MBq ^{241}Am
  - ✓ 380 days before therapy



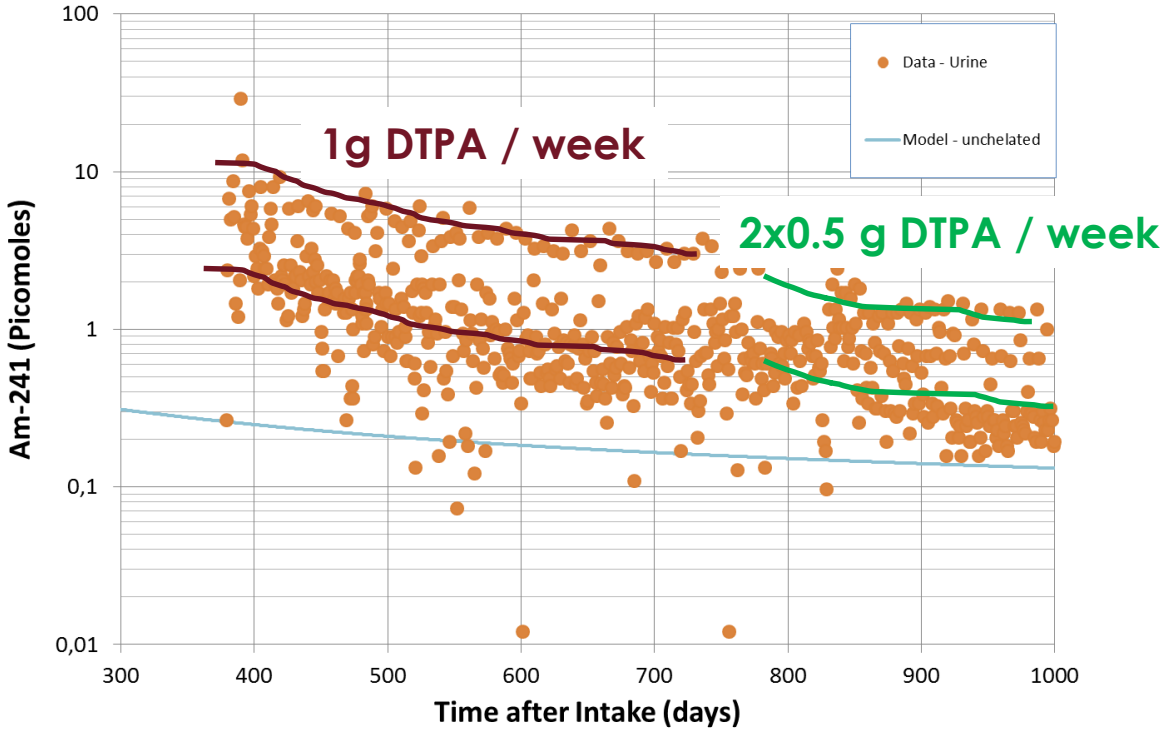
Case 0846 – New Analysis

- CONRAD Model of DTPA therapy
  - ✓ 3 compartmental systems
    - ^{241}Am
    - DTPA (injected)
    - ^{241}Am-DTPA (chelates)
  - ✓ Coupling (2nd order kinetics)
    - Parameter K_C
- Original CONRAD Model
  - ✓ Chelation only in ST0 compartment
- Modified EURADOS Model
  - ✓ Chelation also in other compartments



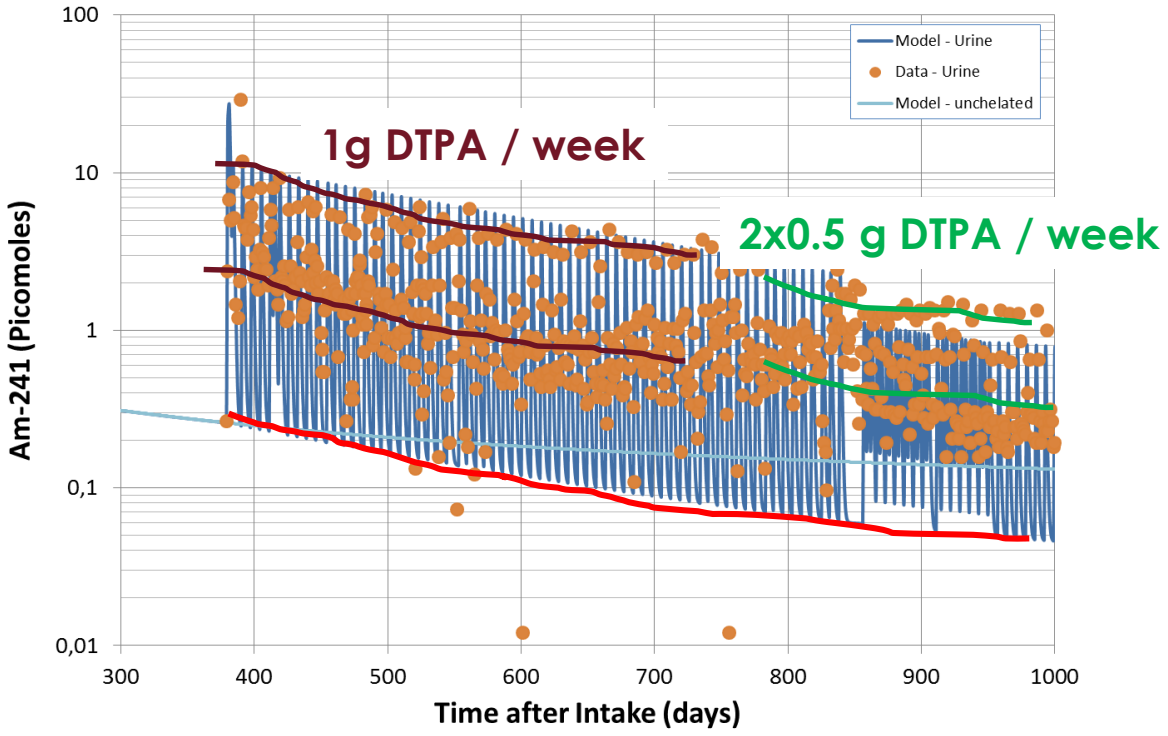
Case 0846 – New Analysis

- Daily urinary excretion data
  - ✓ Effect of DTPA at day after injection
  - ✓ Elevated and steeper Baseline in between
  - ✓ Enhancement factor: ~5



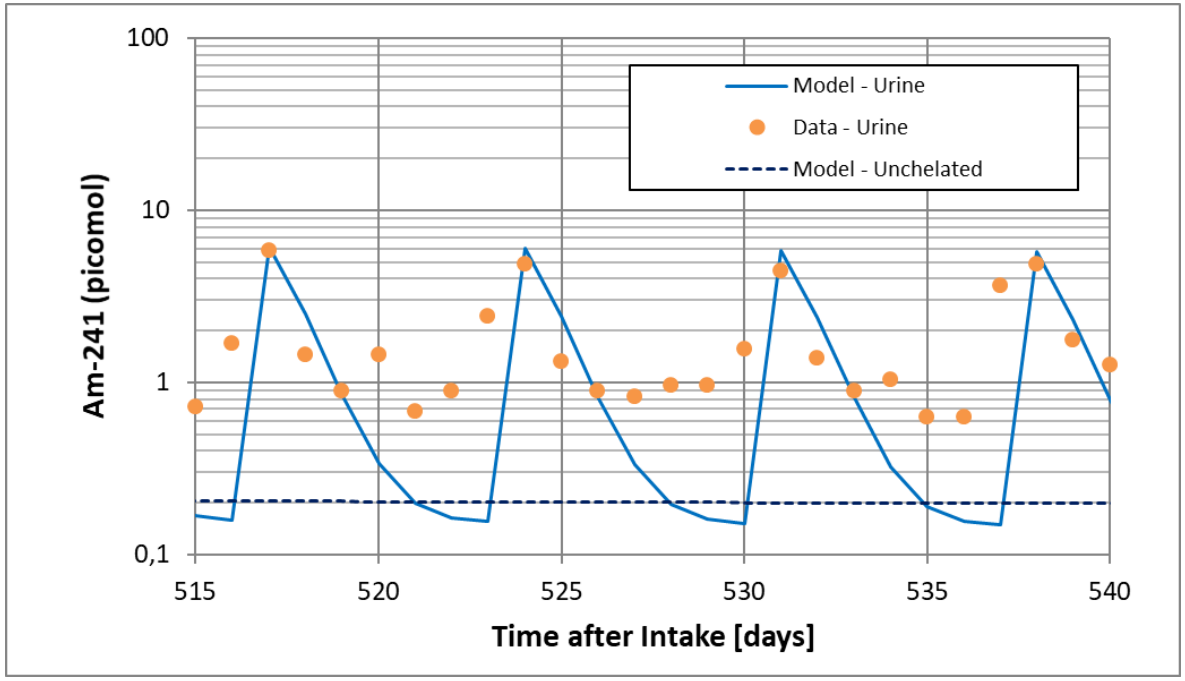
Case 0846 – New Analysis

- Fitting daily urinary excretion data
  - ✓ Chelation constant K_C = 1E-10
  - ✓ 25% of chelation in liver
  - ✓ Model prediction is dropping below unchelated baseline



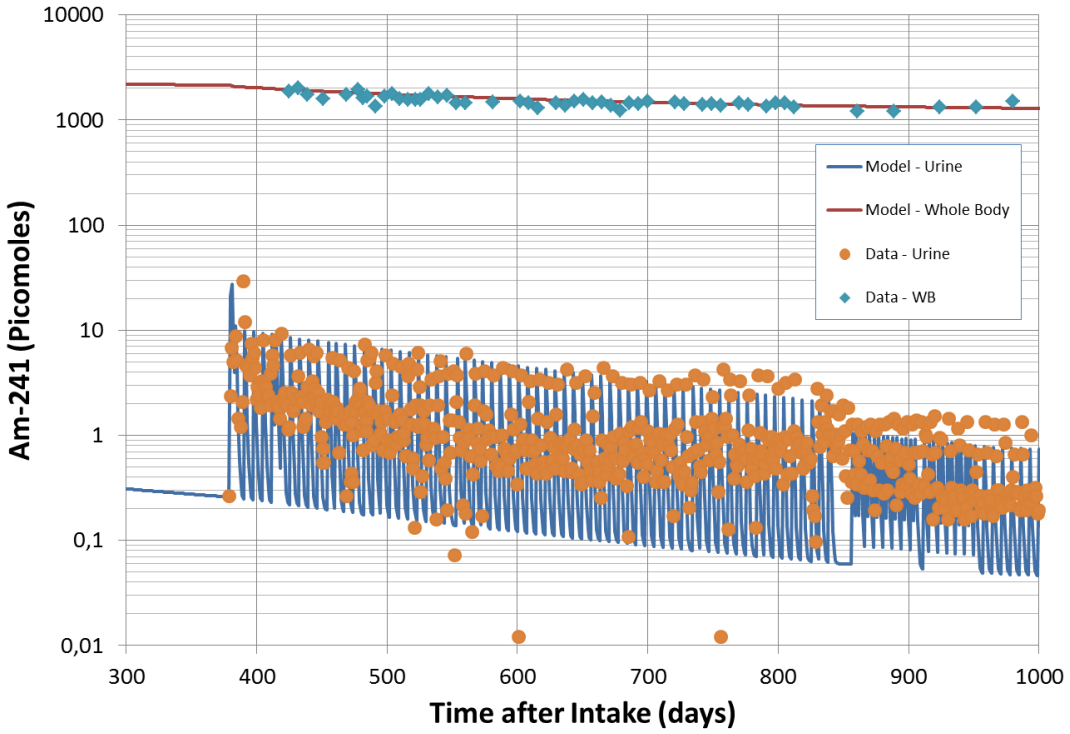
Case 0846 – New Analysis

- Fitting daily urinary excretion data
  - ✓ Chelation constant K_C = 1E-10
  - ✓ 25% of chelation in liver
  - ✓ Model prediction is dropping below unchelated baseline
  - ✓ Removal Half-time of Am-241 DPTA in urine: 2.2 +- 0.7 d
  - ✓ Long-Term effect of DTPA needs to considered in model



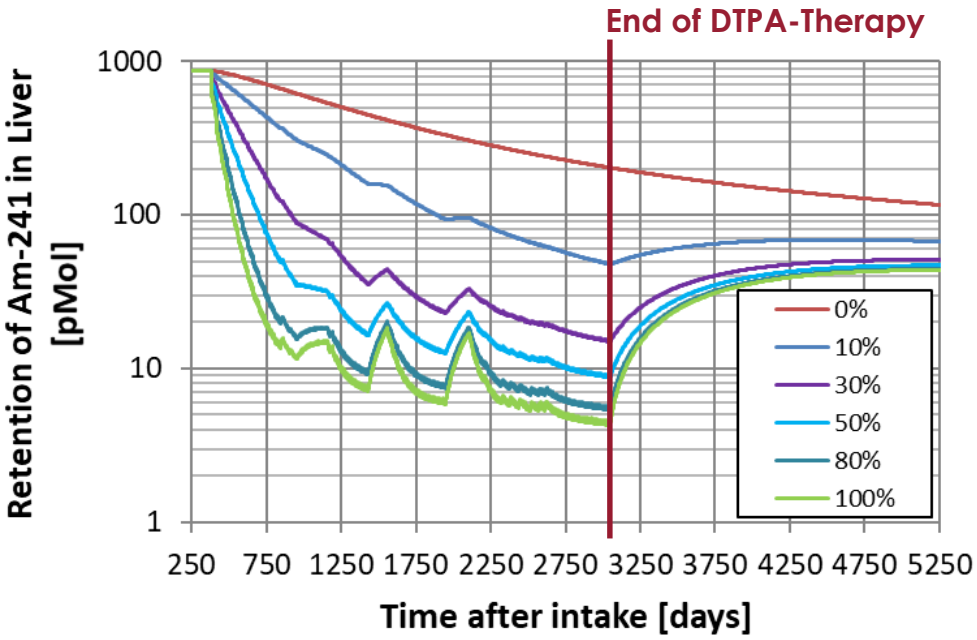
Case 0846 – New Analysis

- Fitting daily urinary excretion and whole body data
  - ✓ K_C = 1E-10 and 25% of chelation in liver
    fit urinary excretion and whole body retention data



Case 0846 – New Analysis

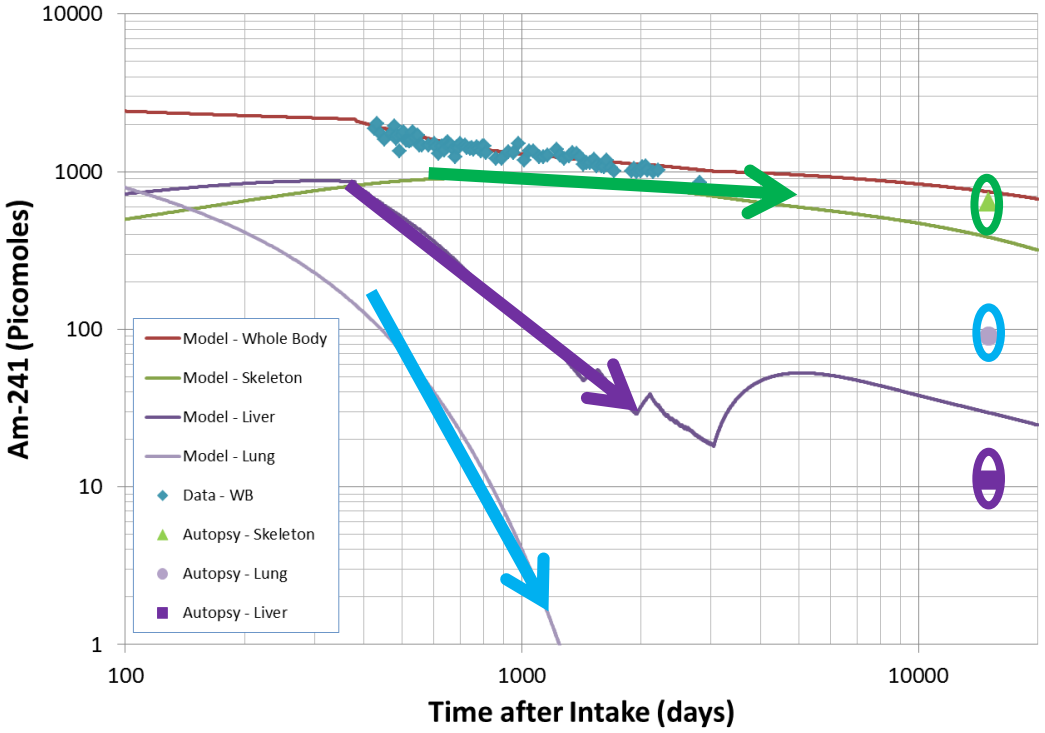
- Effect of different fractions of chelation in liver
  - ✓ Retention in liver depends on fraction
  - ✓ Dose in liver is proportional to area under the curve
    - ✓ Am-241 is an alpha-emitter (→ almost no cross-fire)



% of chelation in Liver	% of area under the curve
No chelation	100
0	99.5
10	59
25	44
30	42
50	37
80	34
100	33

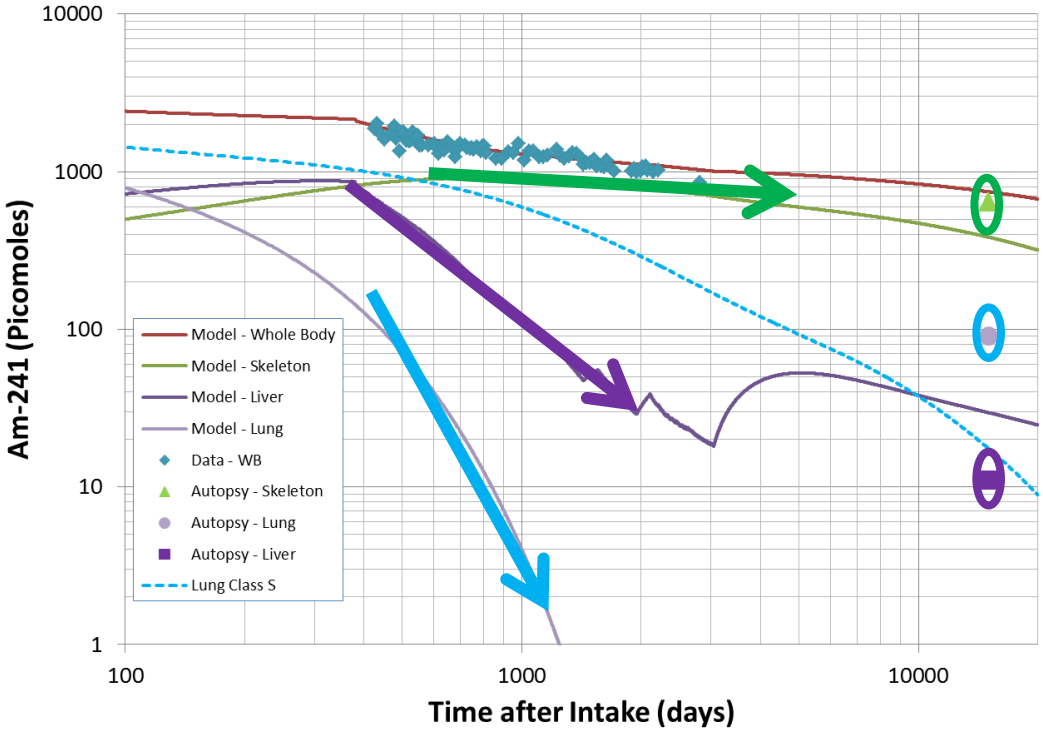
Case 0846 – New Analysis

- Prediction of retention in organs
  - ✓ K_C = 1E-10 and 25% of chelation in liver
  - ✓ Predictions of retention in liver, skeleton and lungs
  - ✓ Acute inhalation of type M material is not a good choice



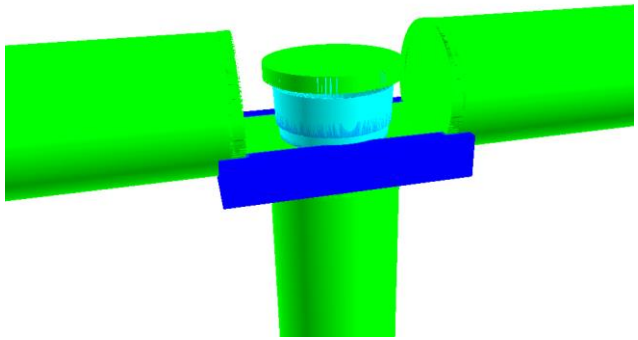
Case 0846 – New Analysis

- Prediction of retention in organs
  - ✓ K_C = 1E-10 and 25% of chelation in liver
  - ✓ Predictions of retention in liver, skeleton and lungs
  - ✓ Acute inhalation of type M material is not a good choice
- The initial scenario needs to be refined



Summary

- The USTUR is unique resource for biokinetic modeling
- USTUR Case 0846
  - ✓ Extensive data set is available
  - ✓ Intake scenario is undefined
    - Many assumptions are required for modeling
  - ✓ Case 0846 contributed to education of students at KIT
    - γ-measurement of 241Am in lung tissue samples
    - MCNP simulations for HPGe detector calibration



Thank you for your Attention

Five Decade Follow-up
of Plutonium and Uranium Workers

Do you have any questions or suggestions on chelation therapy modeling?
Bastian.breustedt@kit.edu is happy to receive and discuss them