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Plutonium Decorporation Following Complex Exposure: *Inception*

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"Learning from Plutonium and Uranium Workers"

Presentation Outline

Part 1:

- United States Transuranium and Uranium Registries
- Plutonium and Decorporation Therapy
- Motivation, Objectives, and Significance

Part 2:

- Case Description
- Materials and Methods
- Preliminary Results
- Conclusions
- Future Directions
- Acknowledgments

PART 1: Introduction

What is USTUR?

- Federally-funded human tissue research program, founded in 1968 and operated by WSU COP since 1992

Follow up occupationally exposed workers, from exposure through full lifespan, by studying the biokinetics (uptake, translocation and retention), and tissue dosimetry of actinides (Pu, Am, and U)

- Performs autopsies and radiochemically analyzes collected tissue samples

- Applies obtained data to refine internal radiation dose assessment methods

USTUR Registrants

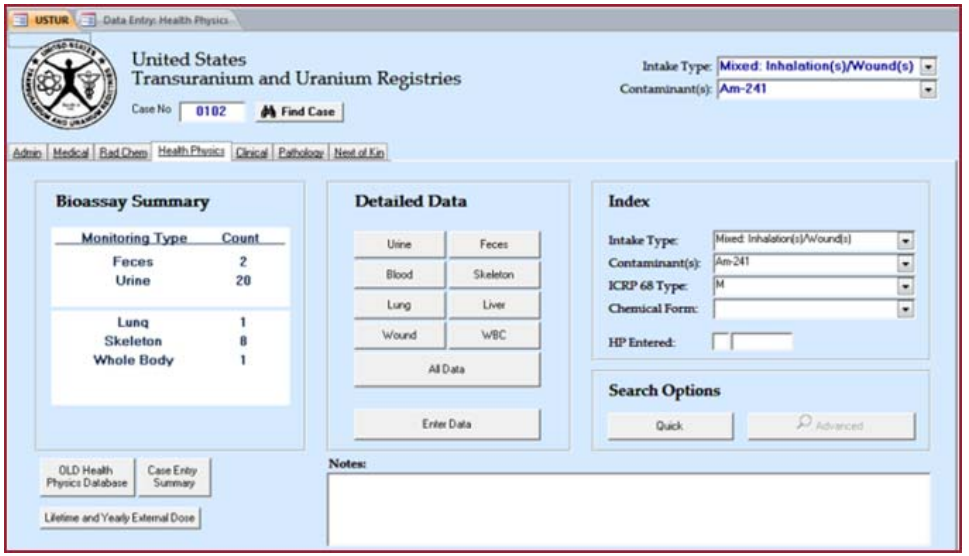
- Former workers from U.S. nuclear facilities
- Known history of exposure to actinides
- Primary radionuclide of exposure: plutonium (83%)
- Acceptance criteria: ≥ 74 decays per sec (Bq)
- 345 voluntary tissue donors (postmortem)
- Primary intake:

  Inhalation (60%)

  Inhalation and wound (complex exposure, 16%)

USTUR Data

- Work History
- Exposure Incidents
- Treatment
- Bioassay Data
- External Dose
- Medical Records
- Radiochemistry Results



Unique Resource of data from former nuclear workers!

Why Plutonium?

- Used in nuclear weapons and nuclear power generation
- Global inventory: 505 tons
- Plutonium in humans

  General public - global fallout

  Occupational - nuclear operation, decommission

- Why do we care?

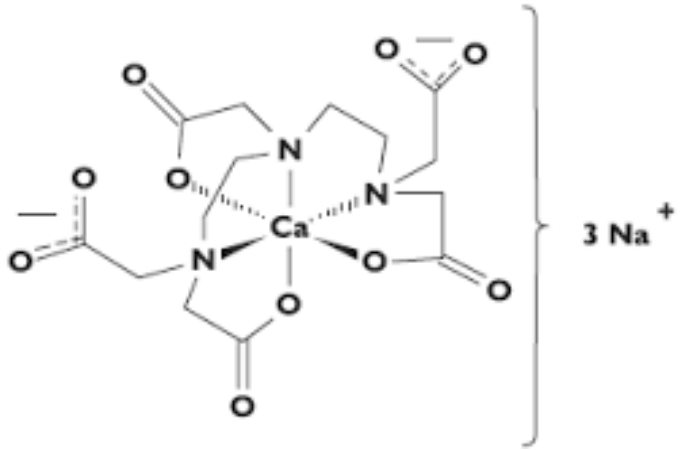
  Nuclear accidents still happen

  'Dirty' bomb threat

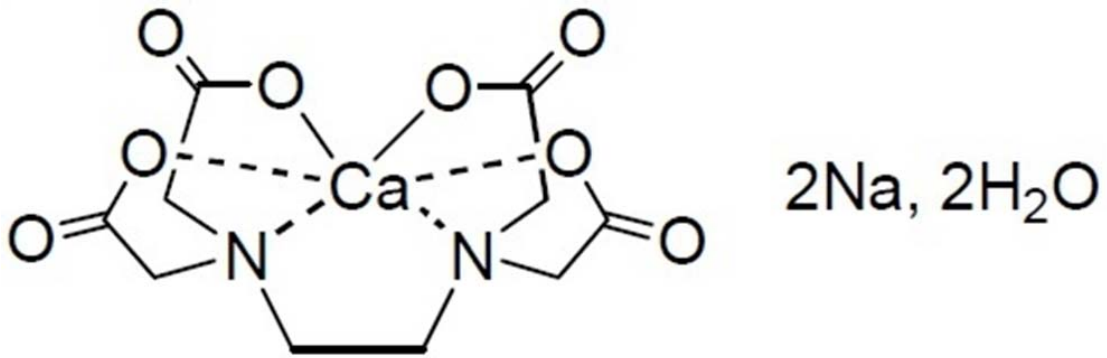
  Compensation claims (12.3 billion dollars)

Decorporation Therapy

- Removal of radioactive elements from the body using specific drugs called chelating agents
- Enhances metal excretion by forming stable complex
- Agents for Plutonium decorporation:



Ca/Zn-DTPA
Diethlyene Triamine Penta Acid



Ca-EDTA
Ethylene Diamine Tetra Acetic Acid

Motivation, Objectives, and Significance

Motivation:

- No accepted model for decorporation

Objectives:

- Develop, parameterize and validate a generic biokinetic model for plutonium decorporation therapy

Significance:

- Interpretation of bioassay measurements under treatment conditions
- Optimization of actinides decorporation treatment

PART 2: Case Study

USTUR Case 0785

- *Time of employment:* 30+ y
- *Complex exposure:* Inhalation and wound
- *Contaminant:* Plutonium nitrate
- *Donation type:* Partial-body
- *Cause of death:* Lung disease
- *Post-exposure time:* 51 y

Accident

- Explosion
- Acute inhalation
- Extensive contamination
- Wound deposition 8,032 Bq of plutonium
- Plutonium systemic burden 7,400 Bq

Five times higher than permissible activity

Treatment

Decorporation Therapy

- Immediately : 1-2 g Ca-EDTA, 2 i.v. per day, 4 weeks
- 9 months post-accident: 2 g Ca-EDTA, 2 i.v. per day, 2 weeks
- 7 years post-accident: 1 g Zn-DTPA, 1 i.v. per week, 10 weeks

Wound Excision

- 3 weeks post-accident: 7,344 Bq of plutonium was removed

Materials and Methods

Human Data

- In-vivo (lung counts)
- In-vitro (urine measurements)
- Autopsy (tissue radiochemical analyses)

Models

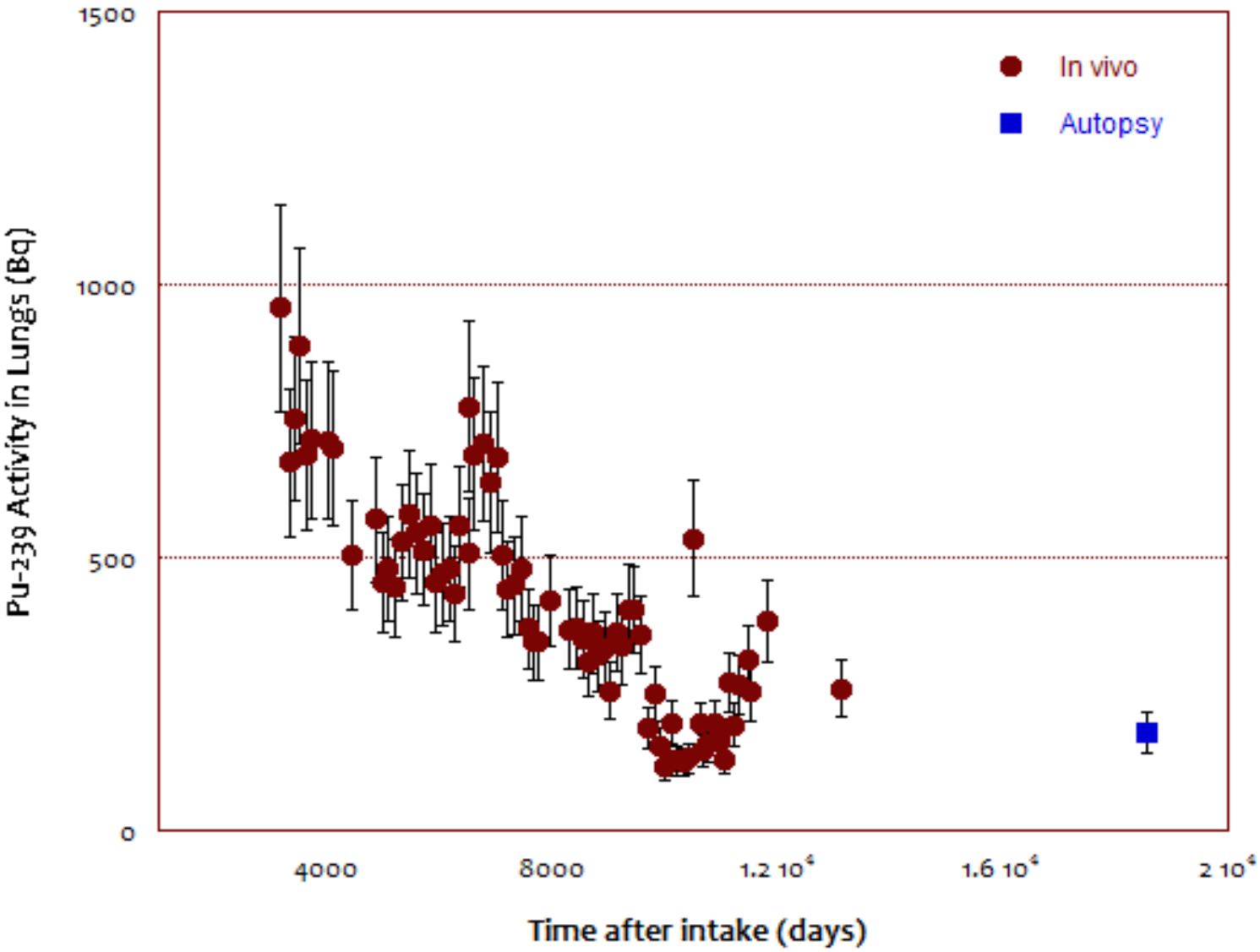
- Human Respiratory Tract Model
- Wound Model
- Systemic Model

Software

- Integrated Models for Bioassay Analysis (IMBA) Professional Plus®

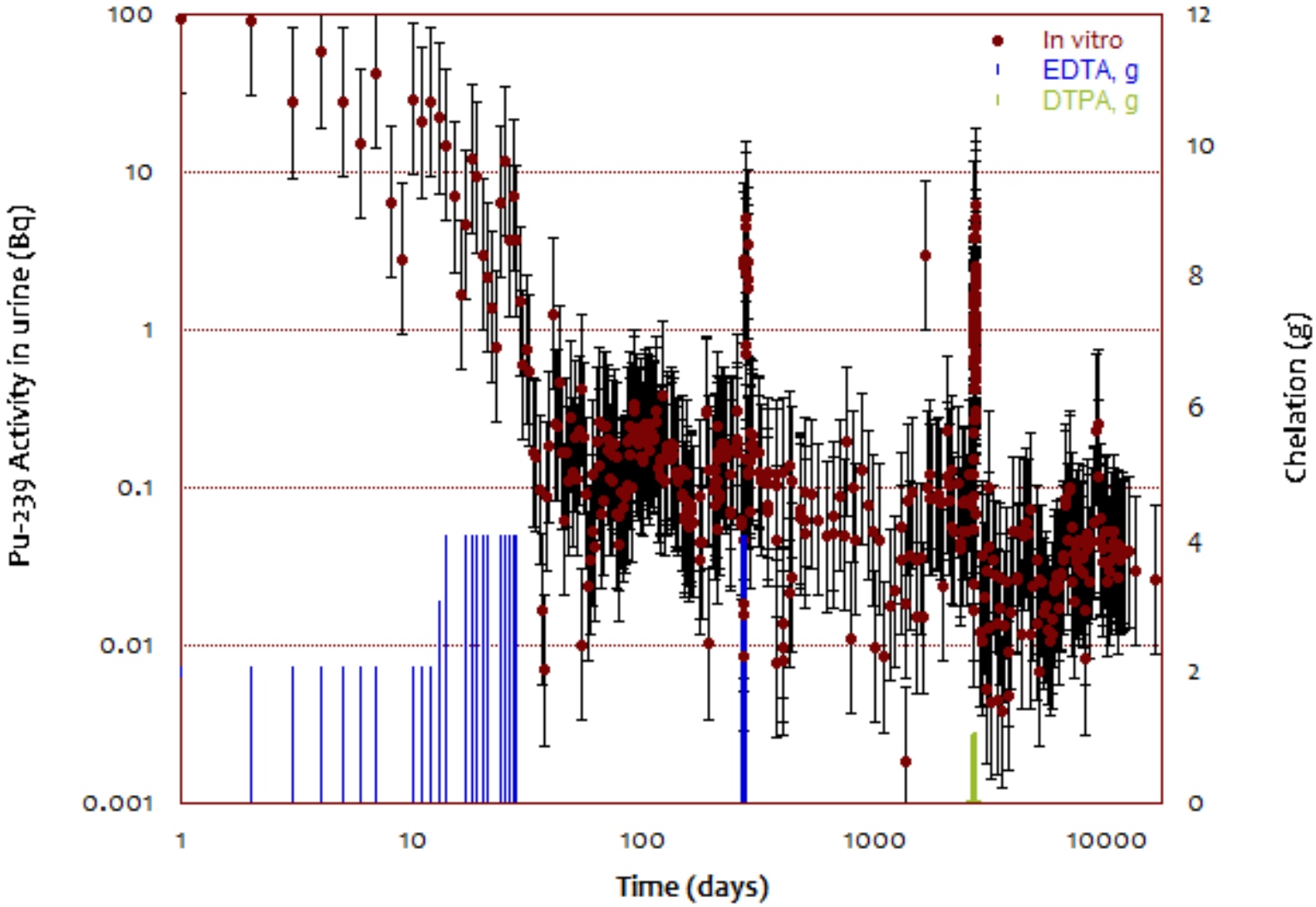
In-Vivo: Lung Counts

- 74 lung measurements



In-Vitro: Urinalysis

- 478 measurements of plutonium in urine



Autopsy: Tissue Analysis

- Total of 32 tissue samples
- Pu concentration measured
- Total tissue/organ activity estimated

Tissue/Organ	Pu Concentration, Bq kg^{-1}	Pu Activity, Bq
Lungs	18.2 ± 0.3	24.6
Thoracic Lymph Nodes (LNTH)	8,199 ± 156	151.4
Liver	548 ± 36	602.0
Skeleton	209 ± 8	1,936
Total Systemic	-------	2,800

- LNTH:Lung ratio = 455 (!!!!) – exposure to very insoluble material

Models Used

Generic Models:

Describe the actinide entry into the human body via inhalation and via the contaminated wounds

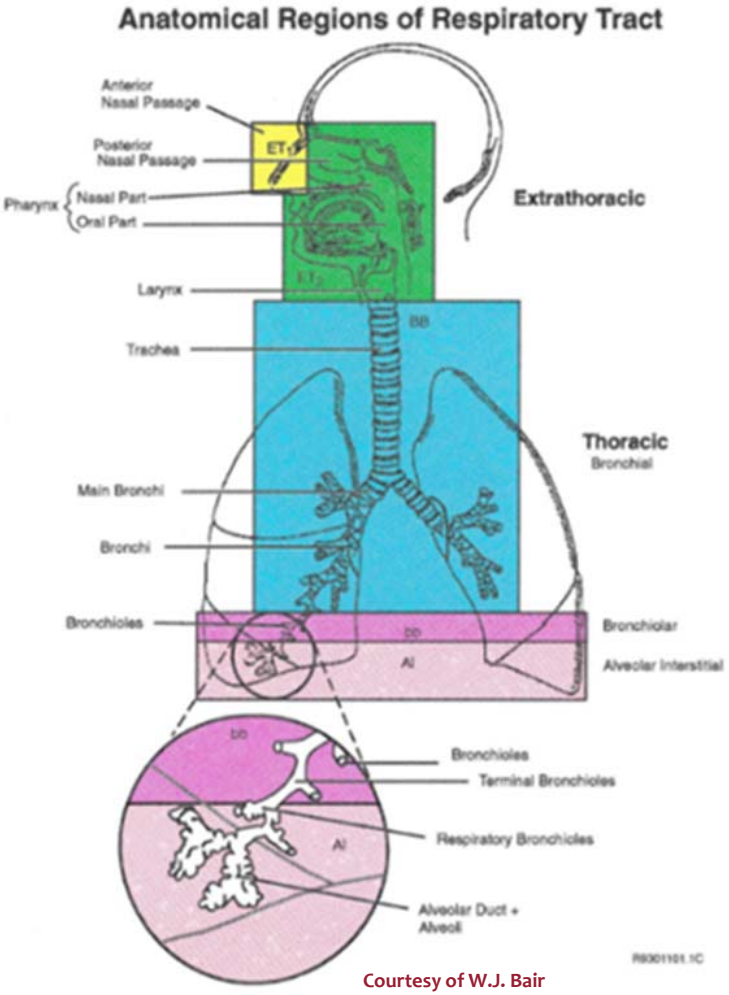
- Human Respiratory Tract Model: International Comission on Radiological Protection (ICRP 130)
- Wound Model: National Council on Radiation Protection and Measurements (NCRP 156)

Systemic Model:

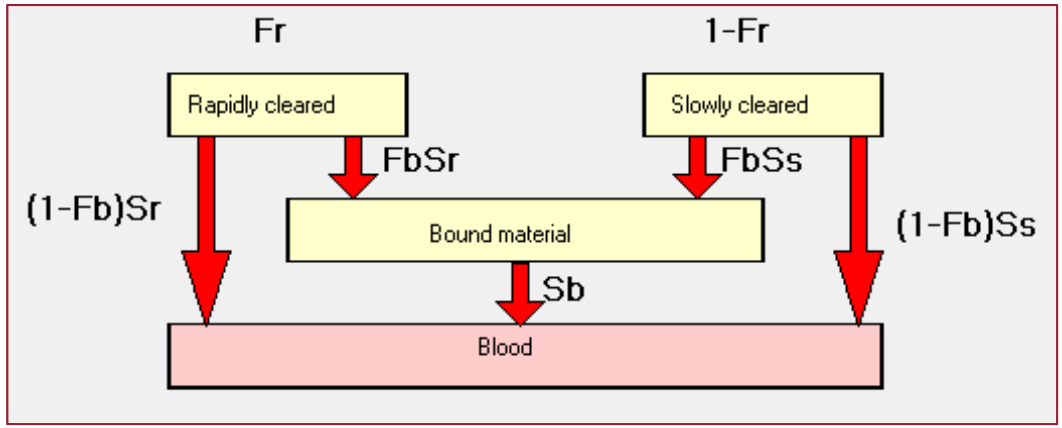
Describe the behavior of radionuclides in the human body upon intake

- Plutonium Systemic Model: Leggett et al, 2005

ICRP Human Respiratory Tract Model

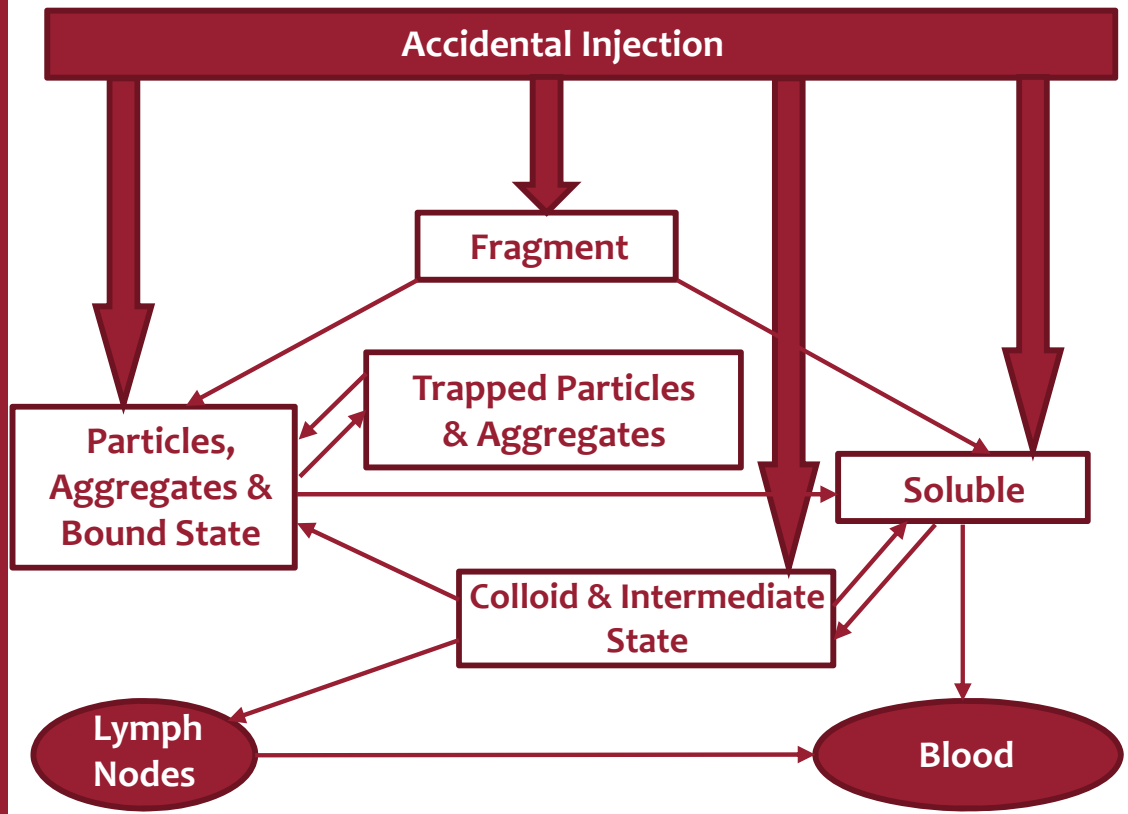


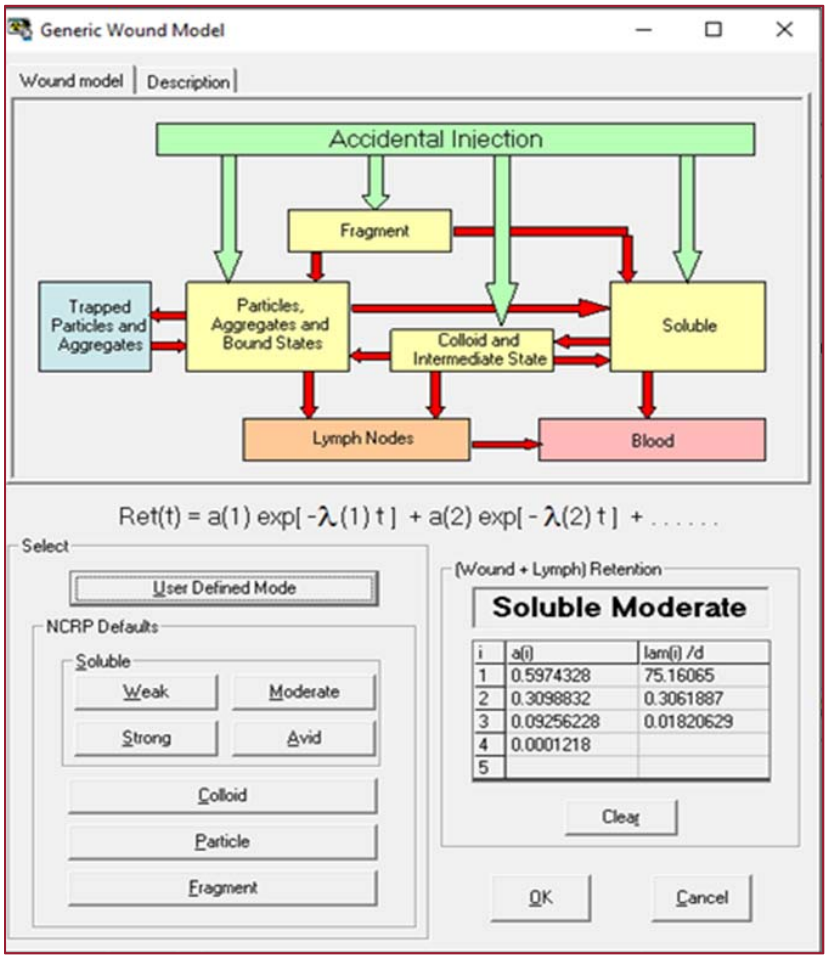
Courtesy of W.J. Bair



Describe how plutonium is absorbed from the respiratory tract into the blood!

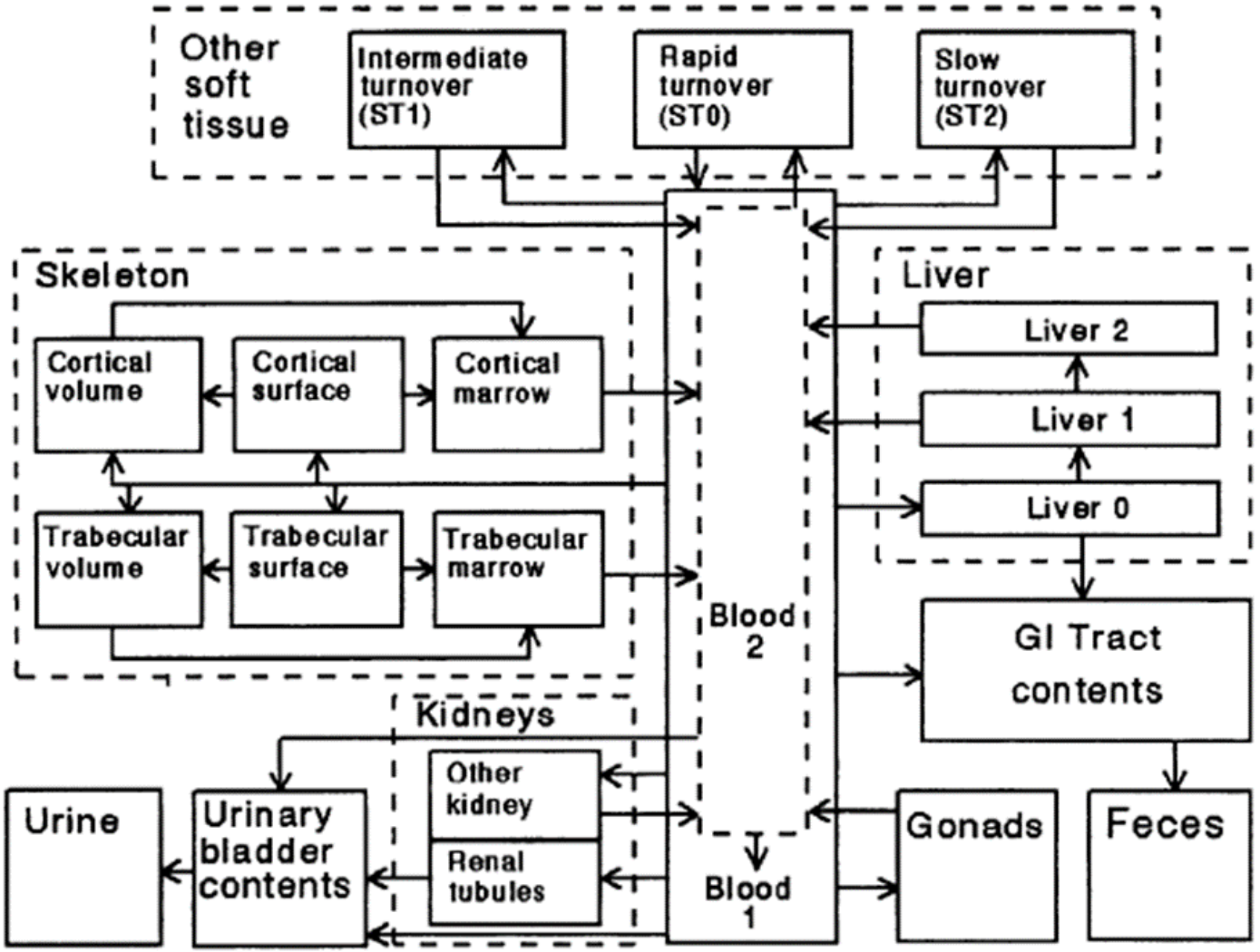
NCRP Wound Model



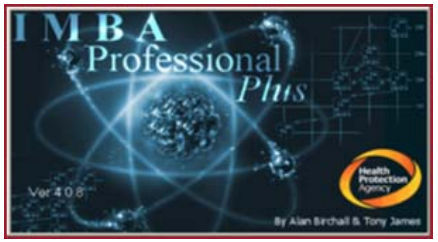


Plutonium Systemic Model

Leggett et al. Mayak Worker Study: An Improved Biokinetic Model for Reconstructing Doses from Internally Deposited Plutonium (2005) Rad Res 164; 111 - 122



IMBA Professional Plus®



IMBA: Integrated Modules for Bioassay Analysis

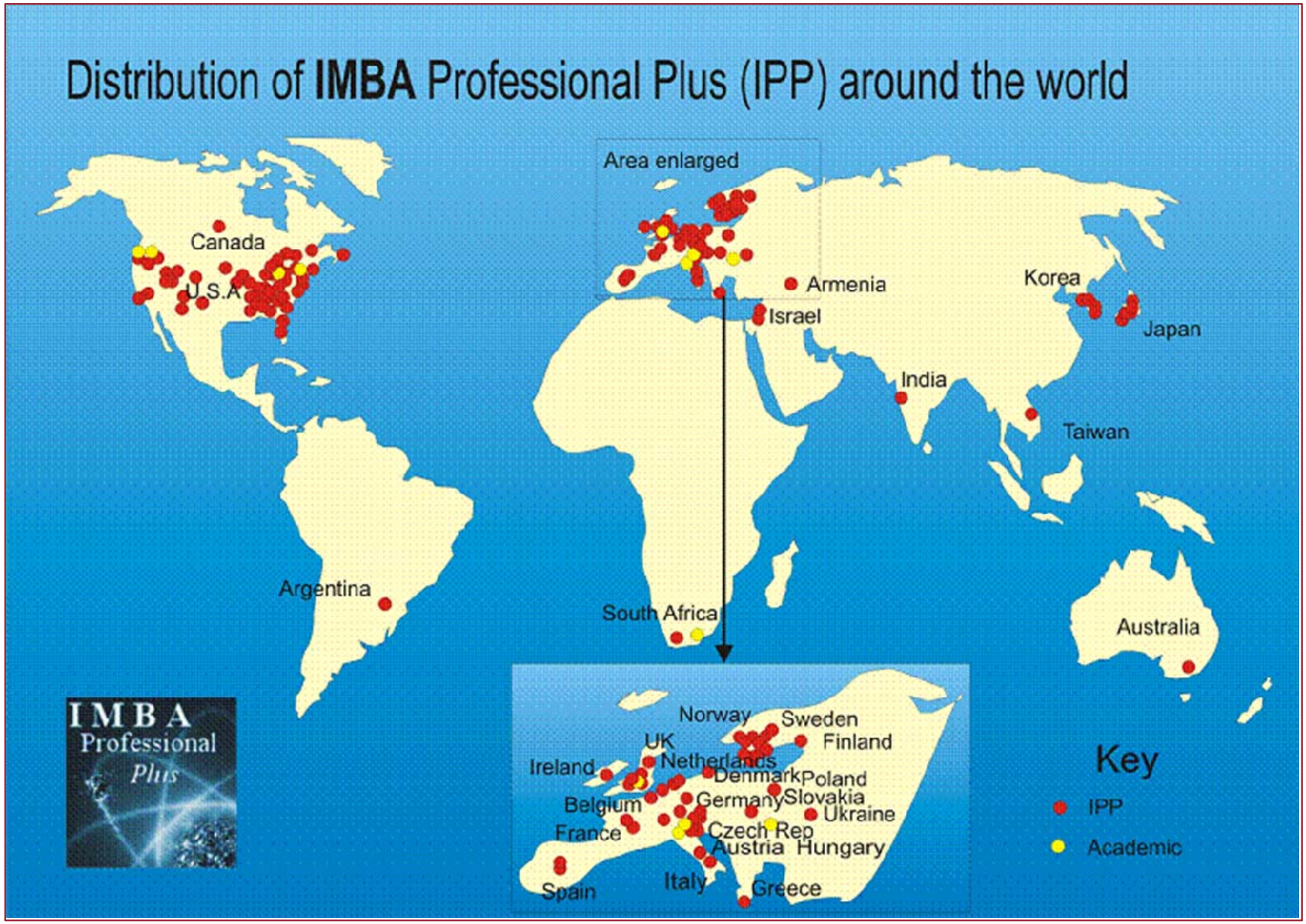
- A suite of software modules for internal dosimetry
- Implements all current biokinetic and dosimetric models
- Enables the user to:

  Assess an intake from bioassay measurement data

  Predict bioassay quantities from a specific intake

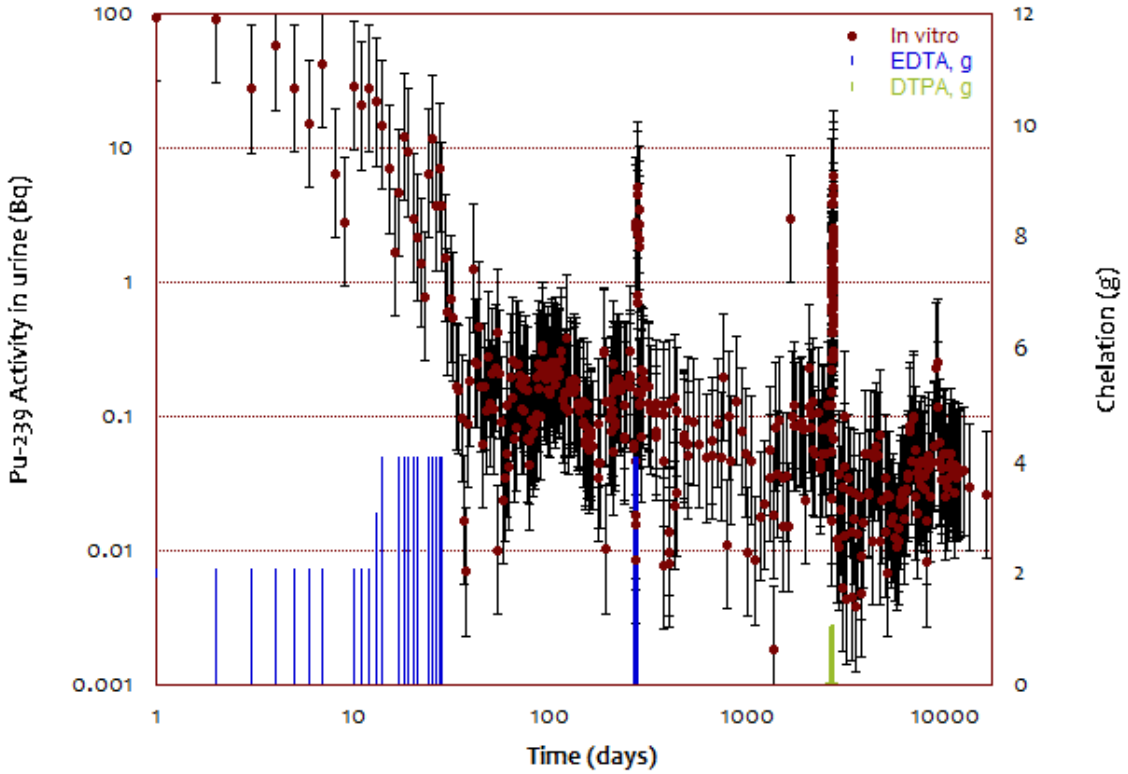
  Calculate resulting doses

IMBA Professional Plus®



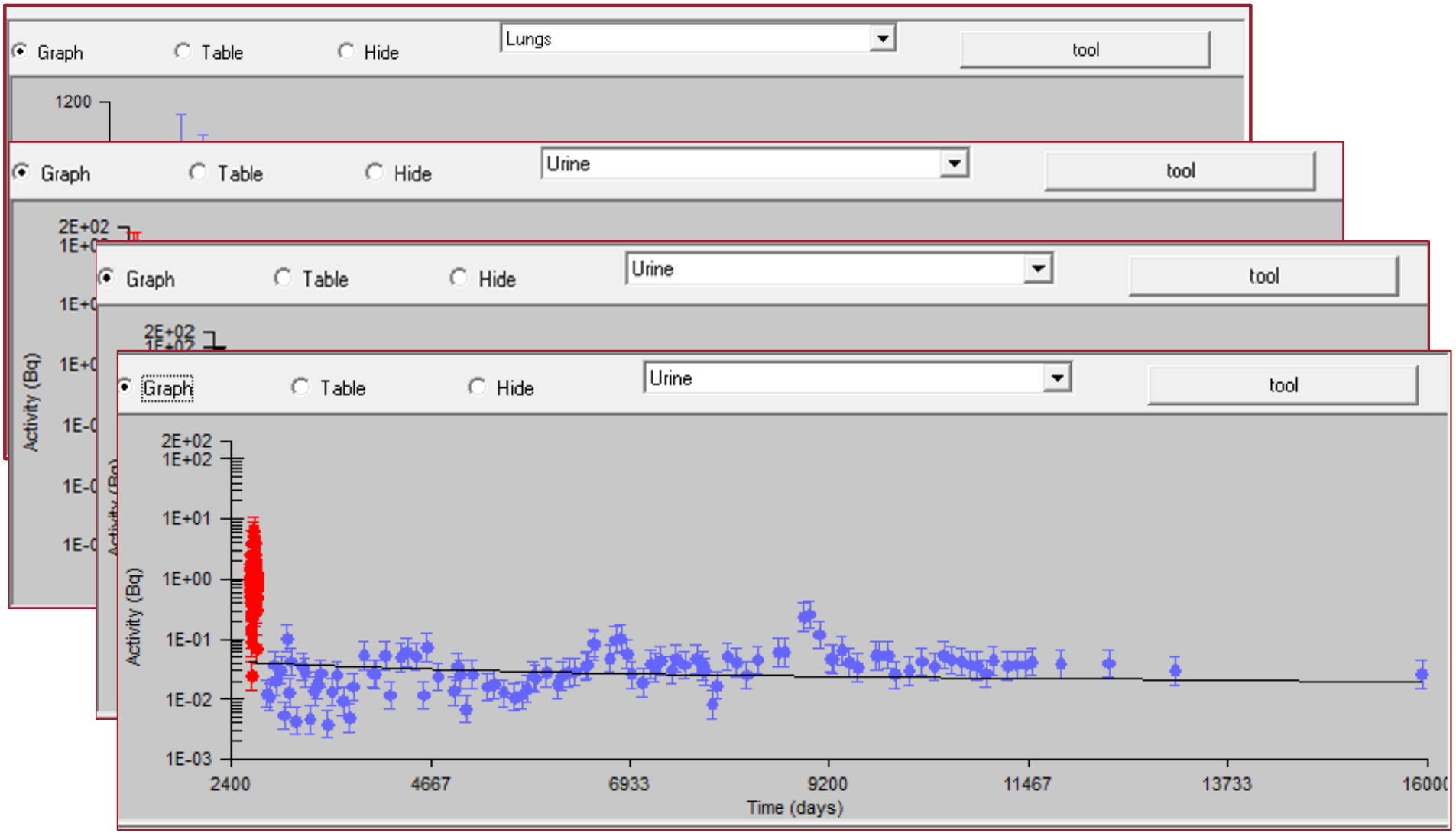
Preliminary Results

Plutonium Decorporation



- Excretion: 683 Bq

Estimating Intake



- Inhalation: 33,050 Bq
- Wound: 1,084 Bq

Conclusions

- Exposure to highly insoluble Pu material
- Estimated intake was 34,817 Bq
- Major internal contamination (97%) from inhalation
- Systemic deposition 51 years post-intake was 2,800 Bq with skeleton-to-liver activity ratio of 3:1

Future Directions

- Modify the default ICRP model parameters to find the best estimate of the intake
- Develop and parameterize plutonium decorporation model
- Validate model using USTUR data (15 cases)

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- Dr. Kathryn Meier
- Dr. Jeannie Padowski
- Dr. Daniel Strom
- Dr. Sergei Tolmachev, *Advisor*

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LASPAU
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CAPES

61st Health Physics Society Meeting

17 – 21 July 2016, Spokane, WA

College of Pharmacy
Washington State University

Special Section: *USTUR: Five Decade Follow-up of Plutonium and Uranium Workers*

- Podium Presentation: *USTUR Case 0785: Modeling Plutonium Decorporation Following Complex Exposure*

Thank you!