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Plutonium Biokinetics in the Human Body Following Decorporation Treatment

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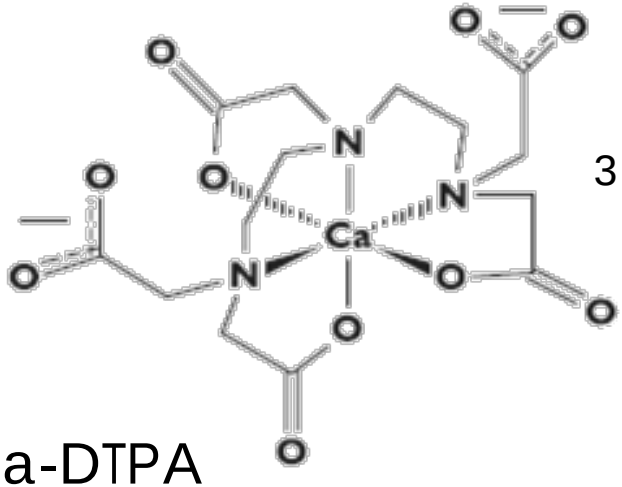
"Learning from Plutonium and Uranium Workers"

Plutonium Facts

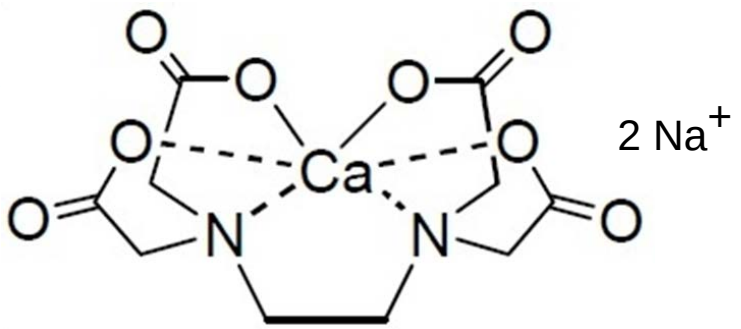
- ^{239}Pu is a major anthropogenic long-lived ($T_{1/2}$ = 24,110 y) radionuclide of plutonium (Pu)
- Used in nuclear weapons and nuclear power generation
- Enters human body as the result of global fallout, industrial accidents, and occupational incidents
- Has a long-term retention in a human body with skeleton and liver as major depository sites
- Highly exposed individuals treated with chelating agents (decorporation therapy)

Decorporation Therapy

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



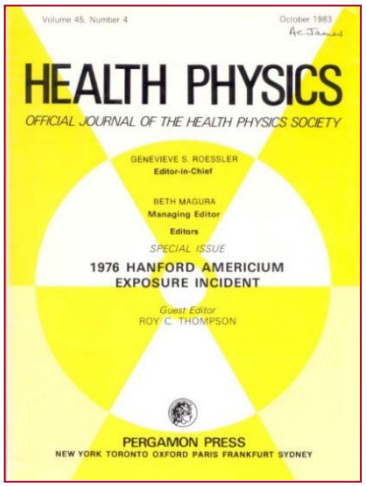
Ca-DTPA
diethylenetriaminepentaacetic acid

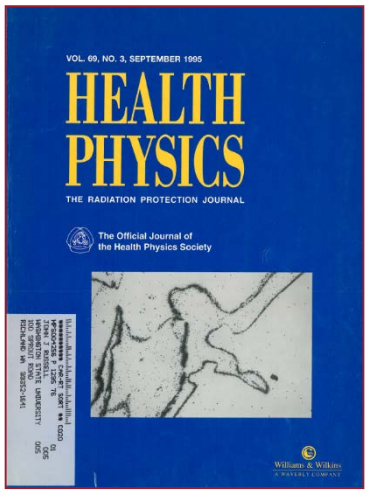


Ca-EDTA
ethylenediaminetetraacetic acid

Atomic Man: Chelation Therapy Saved His Life

- Explosion of ion-exchange column with ~ 150 g of ^{241}Am (19 TBq)
- Estimate of uptake > 40 MBq
- Ca/Zn-DTPA chelation therapy administered
- Systemic deposition after treatment – 0.5 MBq
- Treatment efficacy factor: 80





Motivation and Significance

Motivation:

- No recommended model for plutonium decorporation

Significance:

- Interpretation of bioassay measurements during the therapy
- Optimization of plutonium decorporation treatment

Cases Available at the USTUR

USTUR Case	Route of intake	Treatment			
		Agent	Dosage, g	# of i.v.	Years
0212	**Wound**	**Ca-DTPA**	**0.5 – 1.0**	**47**	**0.5**
0269	Inhalation	Ca-DTPA/EDTA	0.2 – 8.0	161	4.0
0785	Complex	Ca-DTPA/EDTA	1.0 – 2.0	77	7.4

USTUR Case	Route of intake	Treatment			
		Agent	Dosage, g	# of i.v.	Days
0031	Wound	Ca-DTPA	1.0	9	9
0202	Inhalation	Ca-DTPA	1.0	5	5
0303	Wound	Ca-DTPA	0.5 – 1.0	16	60
0407	Inhalation	Ca-DTPA	1.0	5	5
0706	Inhalation	Ca-DTPA	1.0	6	8
0821	Inhalation	Ca-DTPA	1.0	4	4

Materials and Methods

Human Data

- In vivo (lung counts)
- In vitro (urine measurements)
- Post mortem radiochemical analyses of tissues

Software

- Integrated Modules for Bioassay Analysis (IMBA) Professional Plus®
- ModelMaker® version 4 (MM4)

Models

- Human Respiratory Tract Model (ICRP 130, 2015)
- Wound Model (NCRP 156, 2006)
- Systemic Model (Leggett *et al. 2005)*
- CONRAD Model for DTPA therapy (2009)

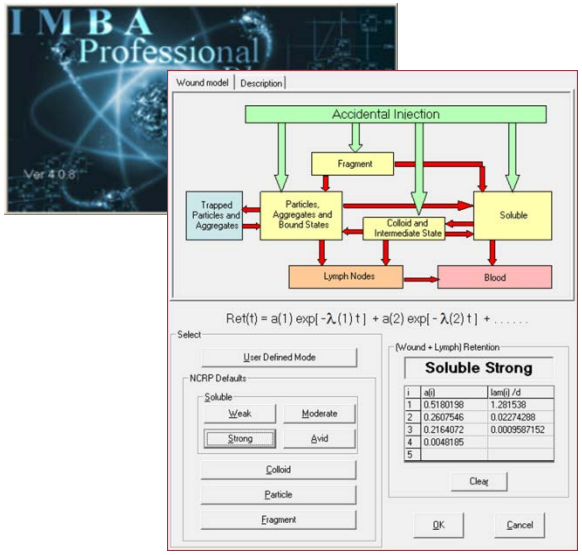
USTUR Whole Body Case 0212

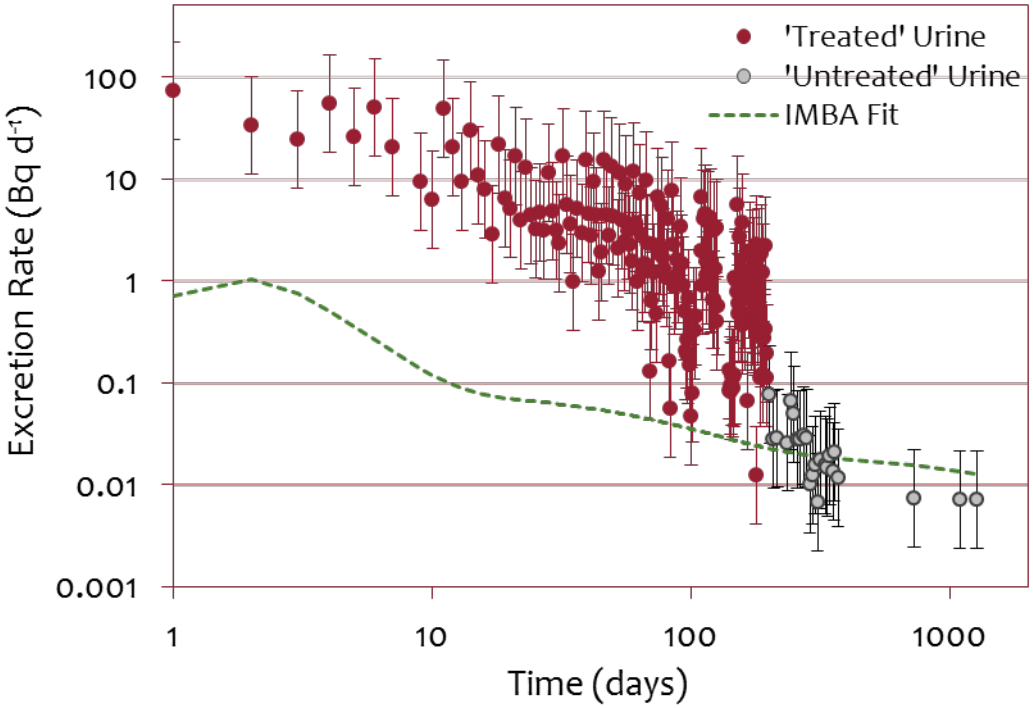
- Exposure: Wound
- Treatment: Tissue excision & Ca-DTPA
- Donation year: 1984
- Time post-intake: 17 y
- Age: 56 y
- Cause of death: Pulmonary emphysema

USTUR Whole Body Case 0212

- Intake
  - IMBA estimate: 294 Bq
  - \+
  - Pu excreted with DTPA: 916 Bq

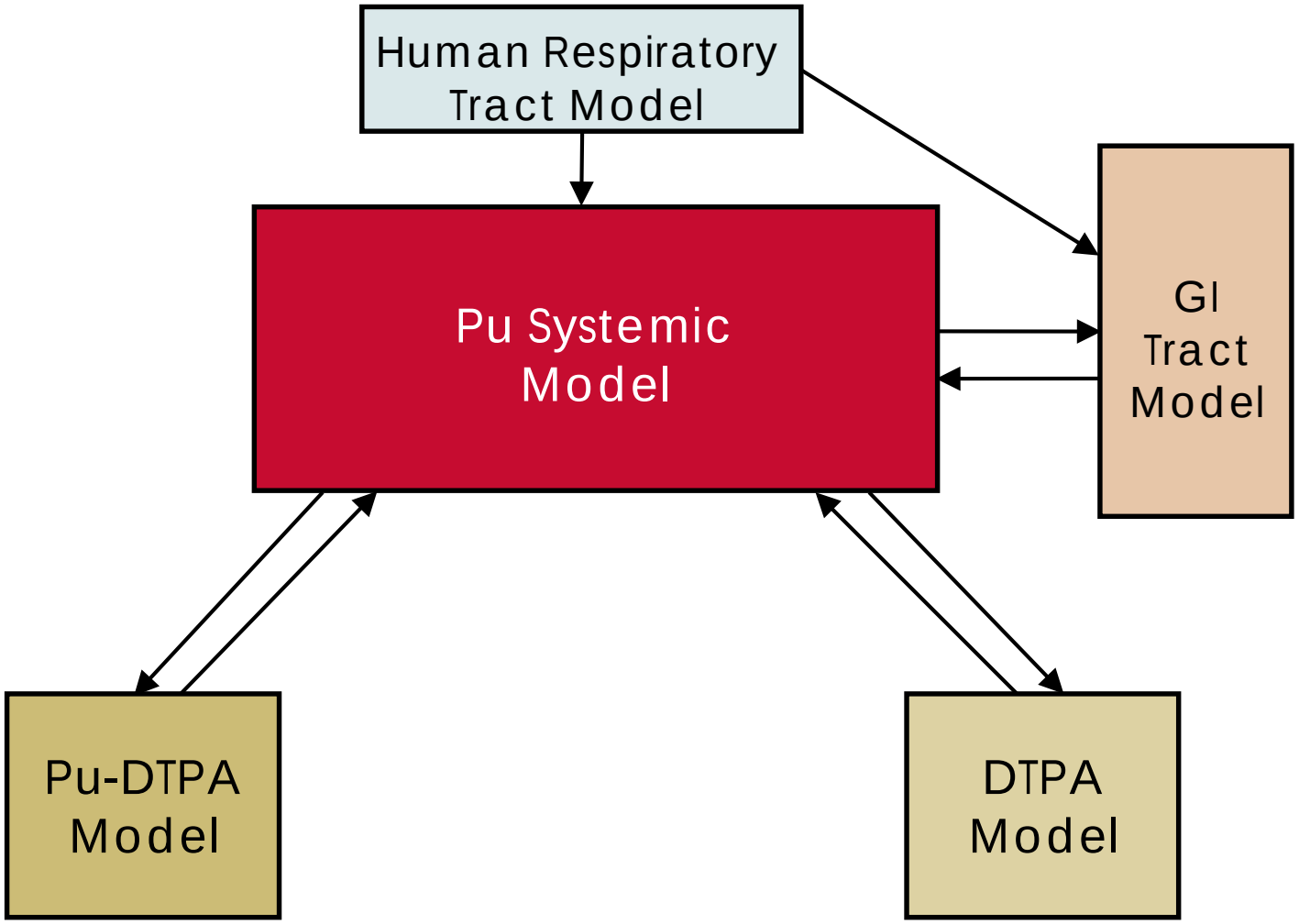
1,210 Bq



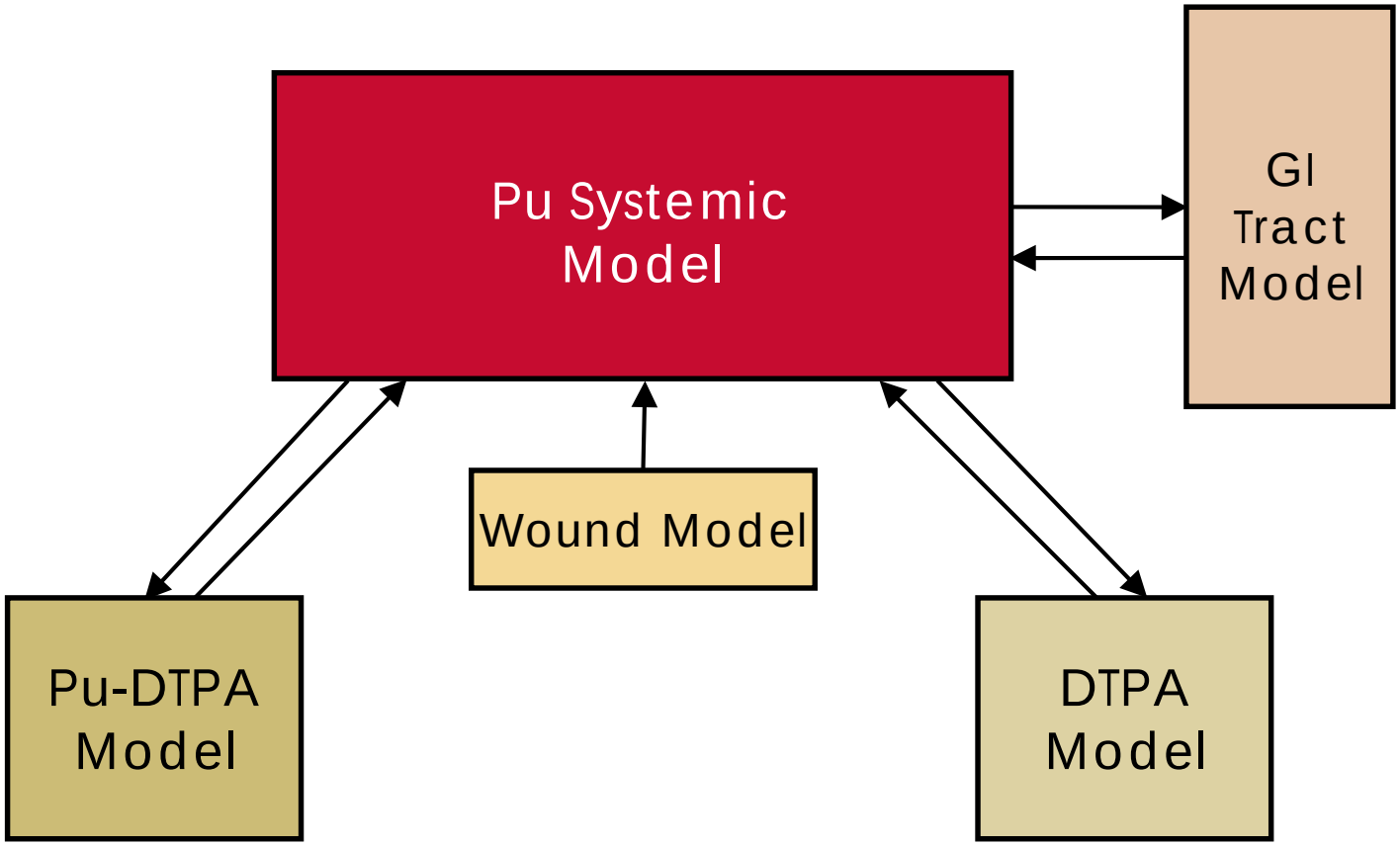


Avtandilashvili, M, Dumit, S. Tolmachev SY. USTUR Case 0212: Testing NCRP 156 Wound Model. Rad. Protect. Dosim. *In preparation*

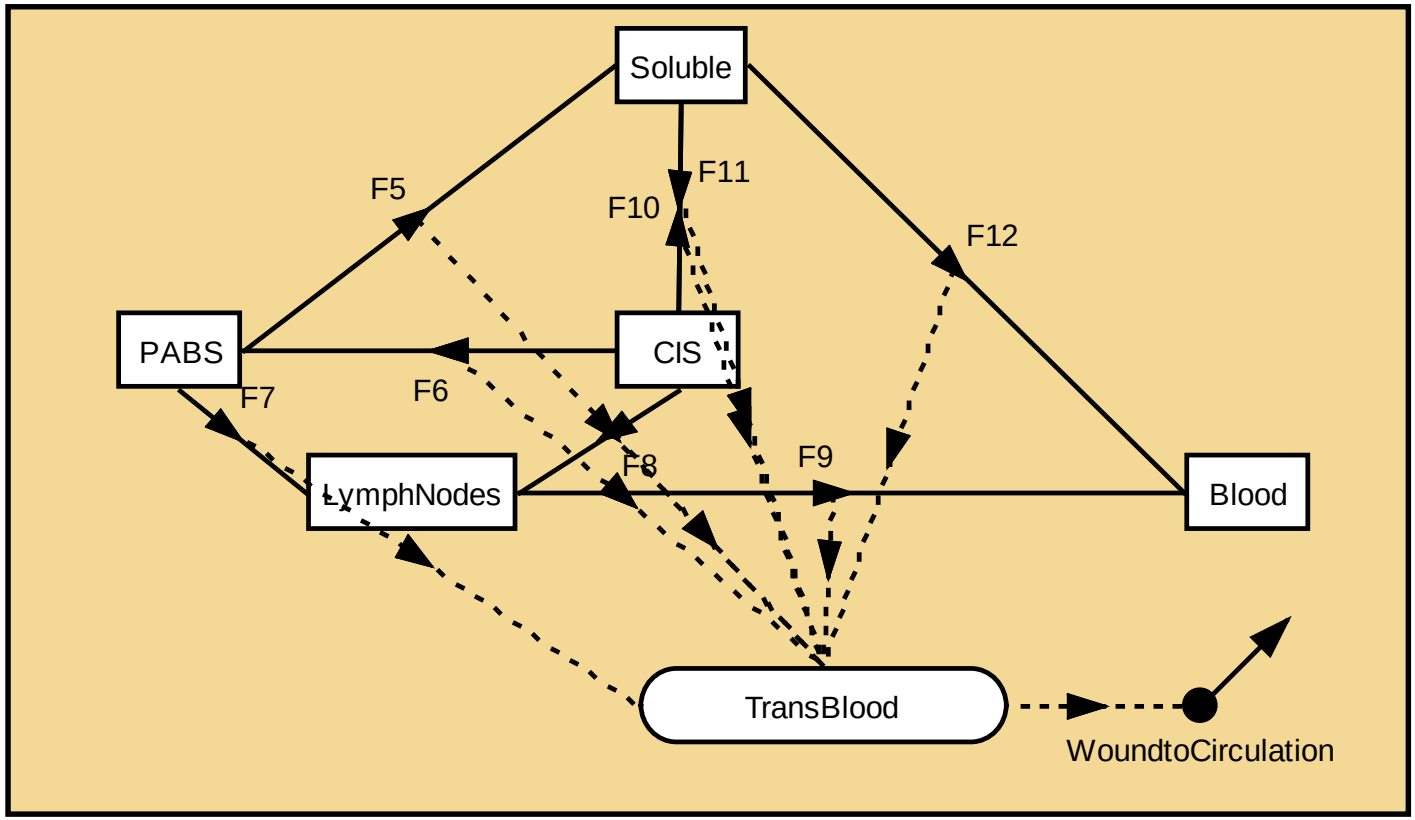
CONRAD Model



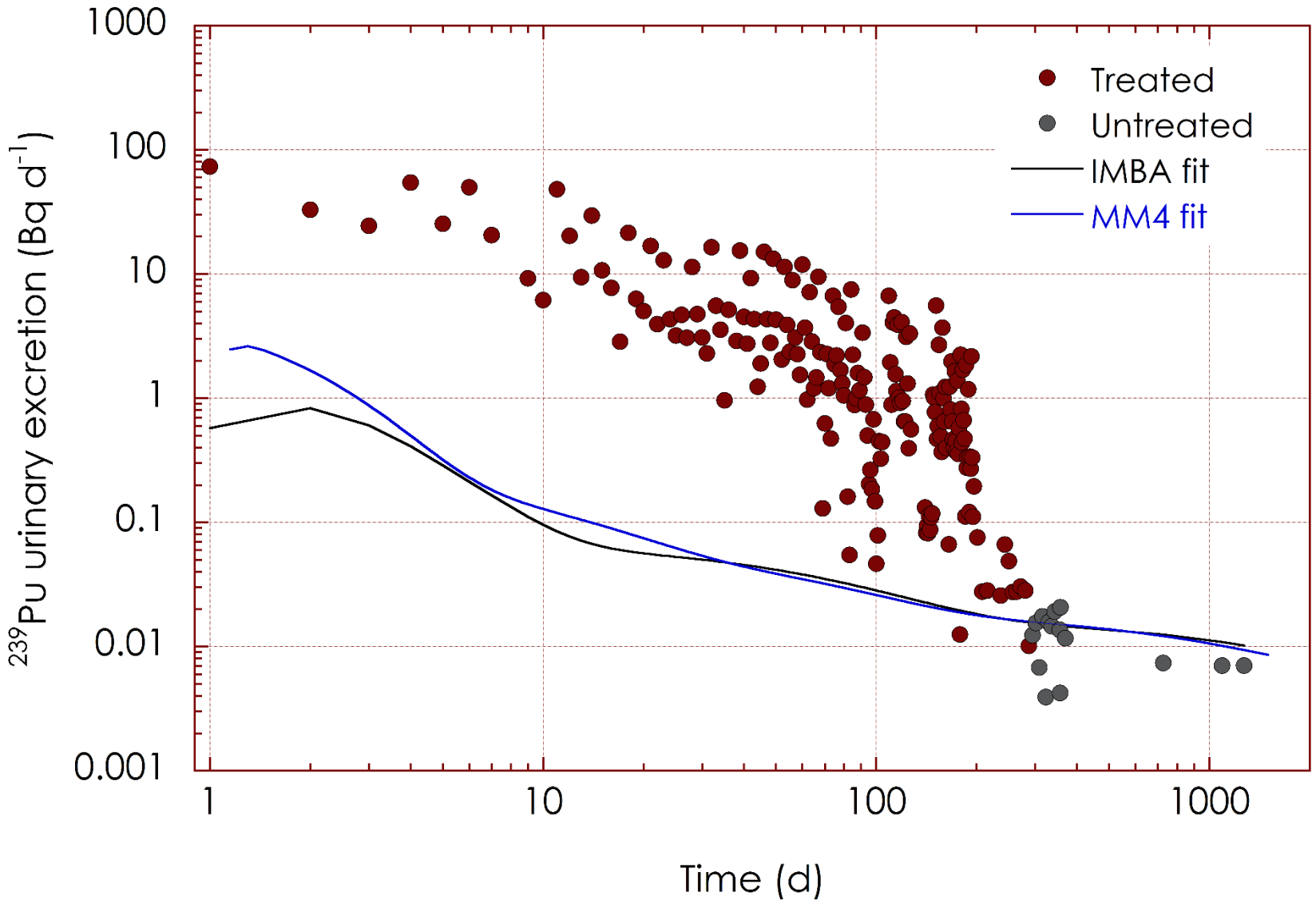
CONRAD Model + Wound Model



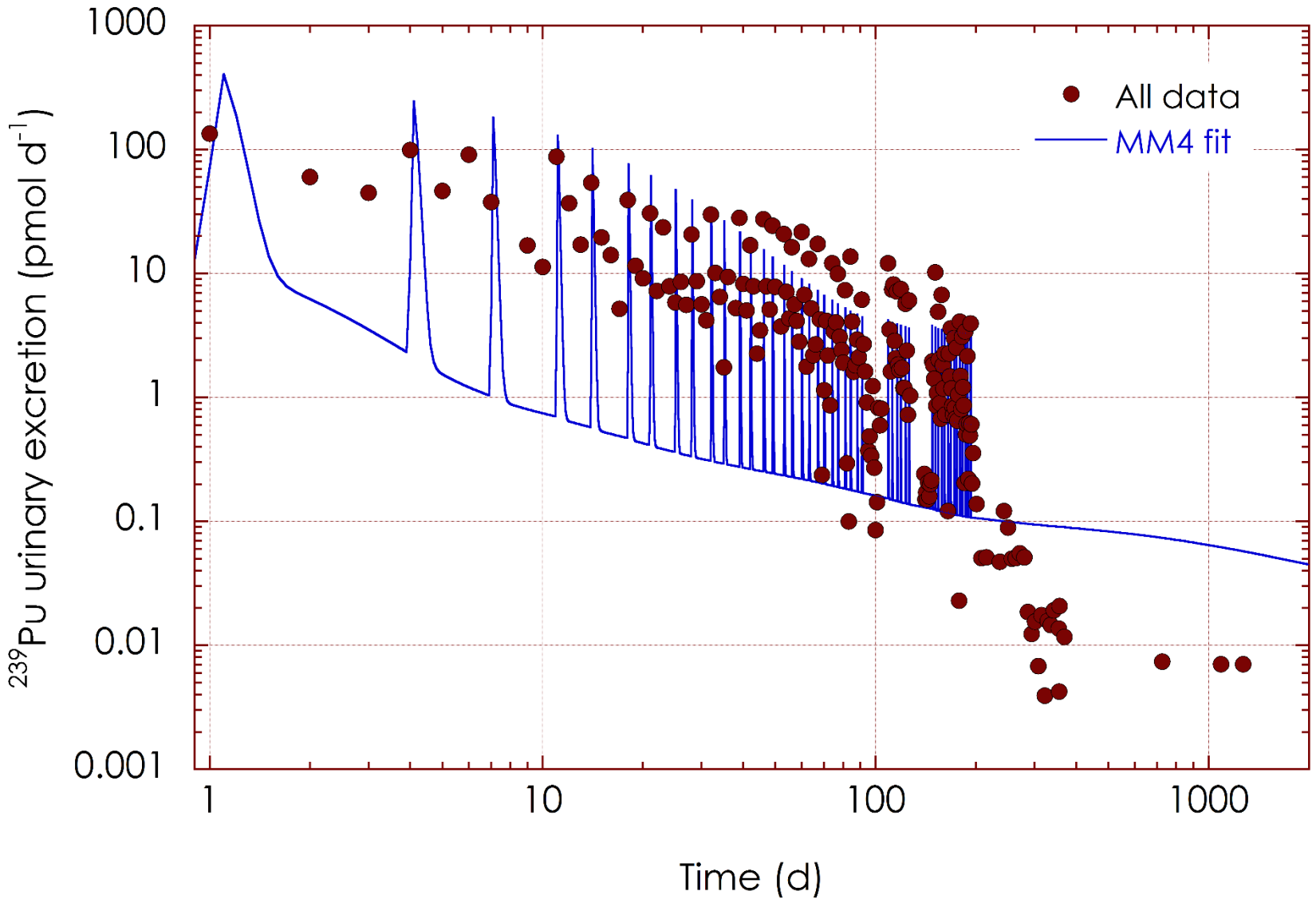
MM4: NCRP 156 Wound Model



Baseline Fit: IMBA vs MM4



Case 0212 Urinary Excretion: MM4 Fit



Summary

- Interpretation of bioassay measurements during the therapy is still challenging
- Preliminary results showed that CONRAD Pu-DTPA model implemented with NCRP Wound Model is able to fit Pu urinary excretion during decorporation treatment
- However, it has limitation in fitting the data not affected by the therapy (baseline)
- Modifications are needed to better fit both: data affected by treatment and baseline data

Future Directions

- Consideration:
  - Initial systemic distribution between Blood1 (70%) and ST0 (30%) compartments
  - Intracellular chelation
  - Evaluation of enhancement factor

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- Dr. Sergei Y. Tolmachev, *Advisor*

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