Mechanistic Wound Modeling

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Pasco, WA

Outline

- Case 262: Analytical Solution of Combined Wound, Auxiliary Lymph Node and Systemic Pu Model System
- New Wound Model according to NCRP 156
- Present Work
- Future Work

Case 262 Summary

- Whole body donation
- Two discrete inhalation intakes followed by puncture wound intake
- The study was concerned about modeling simultaneously the biokinetics of deposition and retention both in the respiratory tract and wound site

Approach to Analyze Data

- The software package IMBA Expert™
  - Derive the amounts and characteristics of two inhalations and the amount of total Pu alpha activity in the puncture wound
  - Subsequent rates of absorption into the blood
- The IMBA estimates were used as initial values to carry out more comprehensive analysis

Compartmental Model Analysis

- The combined wound, auxiliary lymph node and systemic Pu model system was solved analytically using the “rate matrix” method

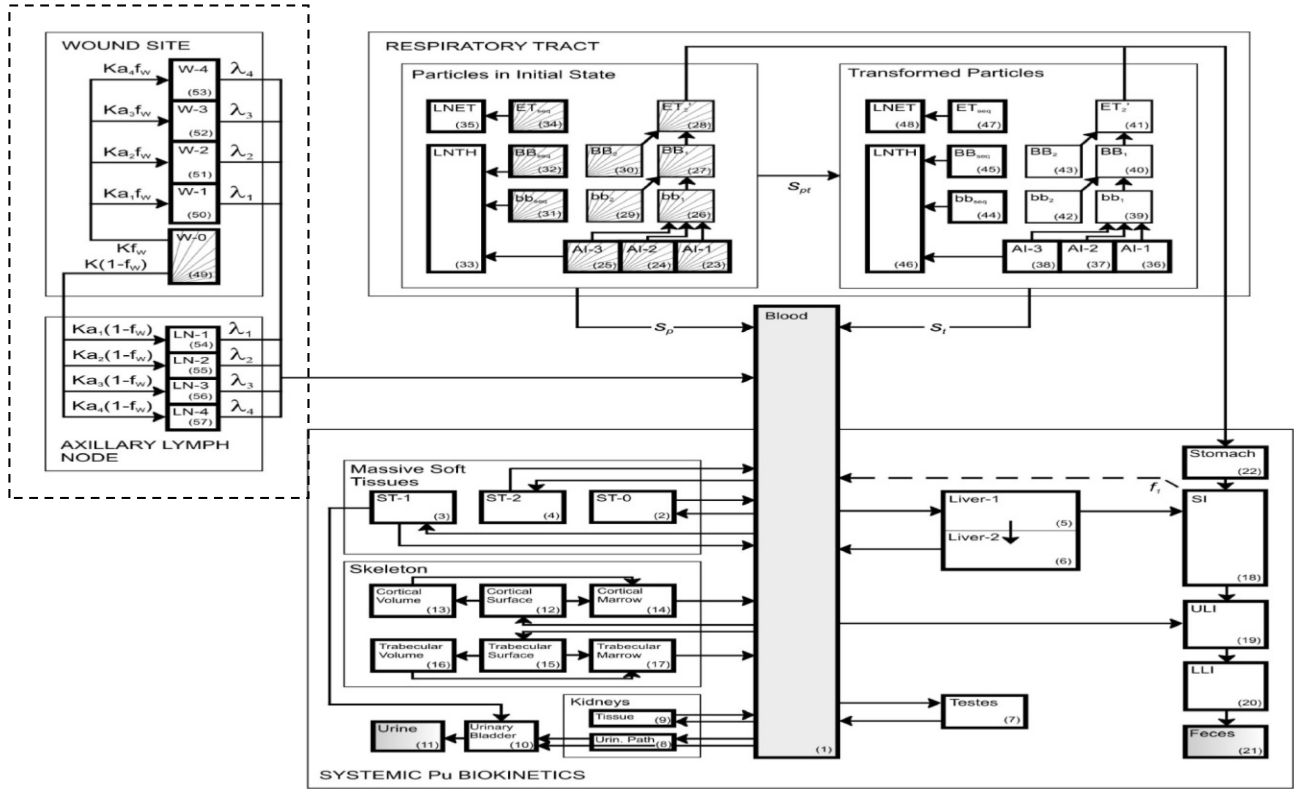


Figure 1: Composite inhalation/wound biokinetic system

Results

Tissue	Content of $^{239+240}$Pu (Bq)		
	Measured	IC67 Model	Error (%)
Wound	68.0	68.0	0
Axillary lymph node	56.0	56.0	0
Lung	2.59	2.59	0
Thoracic lymph nodes	1.05	1.05	0
Skeleton	29.1	33.2	+ 14
Trabecular bone	17.6	9.2	− 48
Cortical bone	11.5	24.0	+ 109
Red bone marrow	–	0.82	–
Liver	20.7	20.0	− 3
Massive soft tissues	8.6	5.3	− 38
Testes	0.018	0.025	+ 39
Kidneys	0.053	0.061	+ 15

Table 1: Best-fit tissue contents predicted by ICRP 67 Pu Biokinetics with ICRP 66 parameter values optimized for Case 262

Transfer pathway	Transfer rate (d^{-1})	
	IC66/67 reference value	Case 0262 factor
Respiratory tract (IC66)		
AI3 to bb1	0.0001	× 0.918
AI3 to LNTH	0.00002	× 0.526
Systemic Pu model (IC67)		
Blood to cortical bone surface	0.3235 × 0.4	× 0.444
Cortical bone volume to marrow	0.0000821	× 0.53
Blood to trabecular bone surface	0.3235 × 0.6	× 1.133
Trabecular bone surface to volume	0.000247	× 1.40
Trabecular bone volume to marrow	0.000493	× 0.35
Trabecular marrow to blood	0.0076	× 0.605
Blood to liver 1	0.1941	× 0.928
Liver 2 to blood	0.000211	× 0.90
Blood to other kidney tissue	0.00323	× 0.827
Blood to urinary path	0.00647	× 0.90
Blood to urinary bladder content	0.0129	× 0.90
Blood to ST-2	0.0129	× 1.84
Blood to testes	0.00023	× 0.69

Table 2: Optimised ICRP 66/67 parameter values for case 262

New Wound Model, NCRP 156

- NCRP report no. 156 was published at the end of 2007
- Wound site is comprised of five compartments in addition to blood and lymph nodes, which are clearance sites

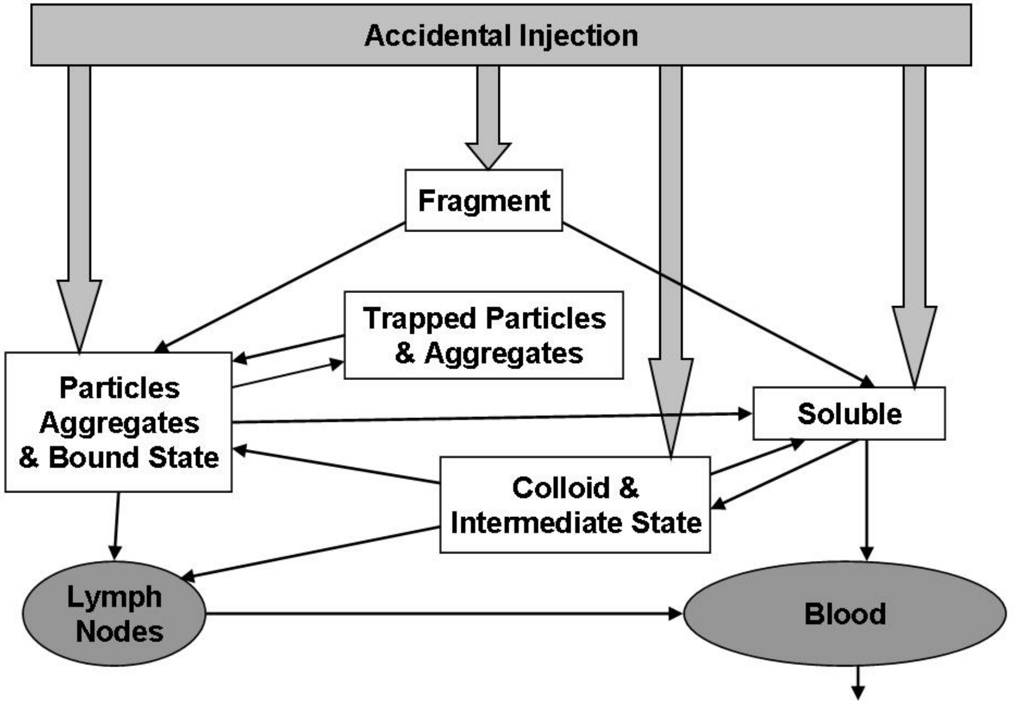
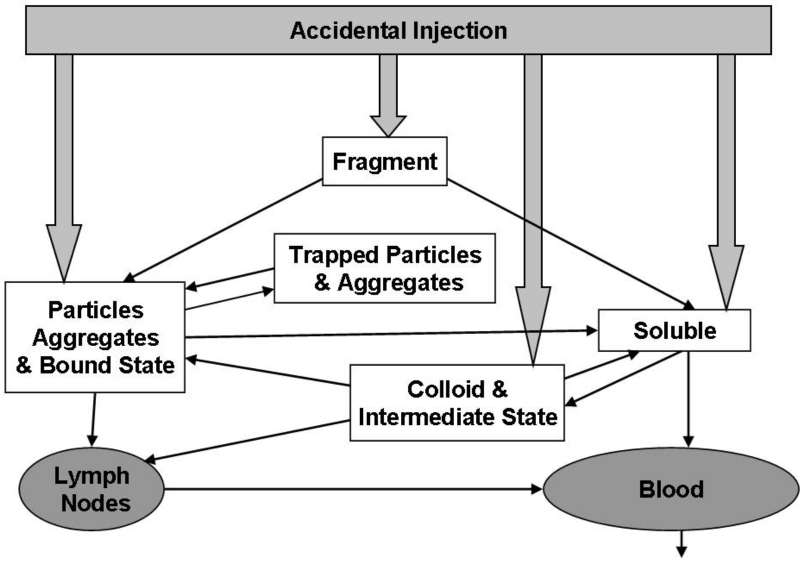


Figure 2: General Compartment Model of the Biokinetics of radionuclides and/or radioactive materials deposited in the wound

Physical and Chemical Properties

- Solution
- Colloidal
- Particulate
- Fragment

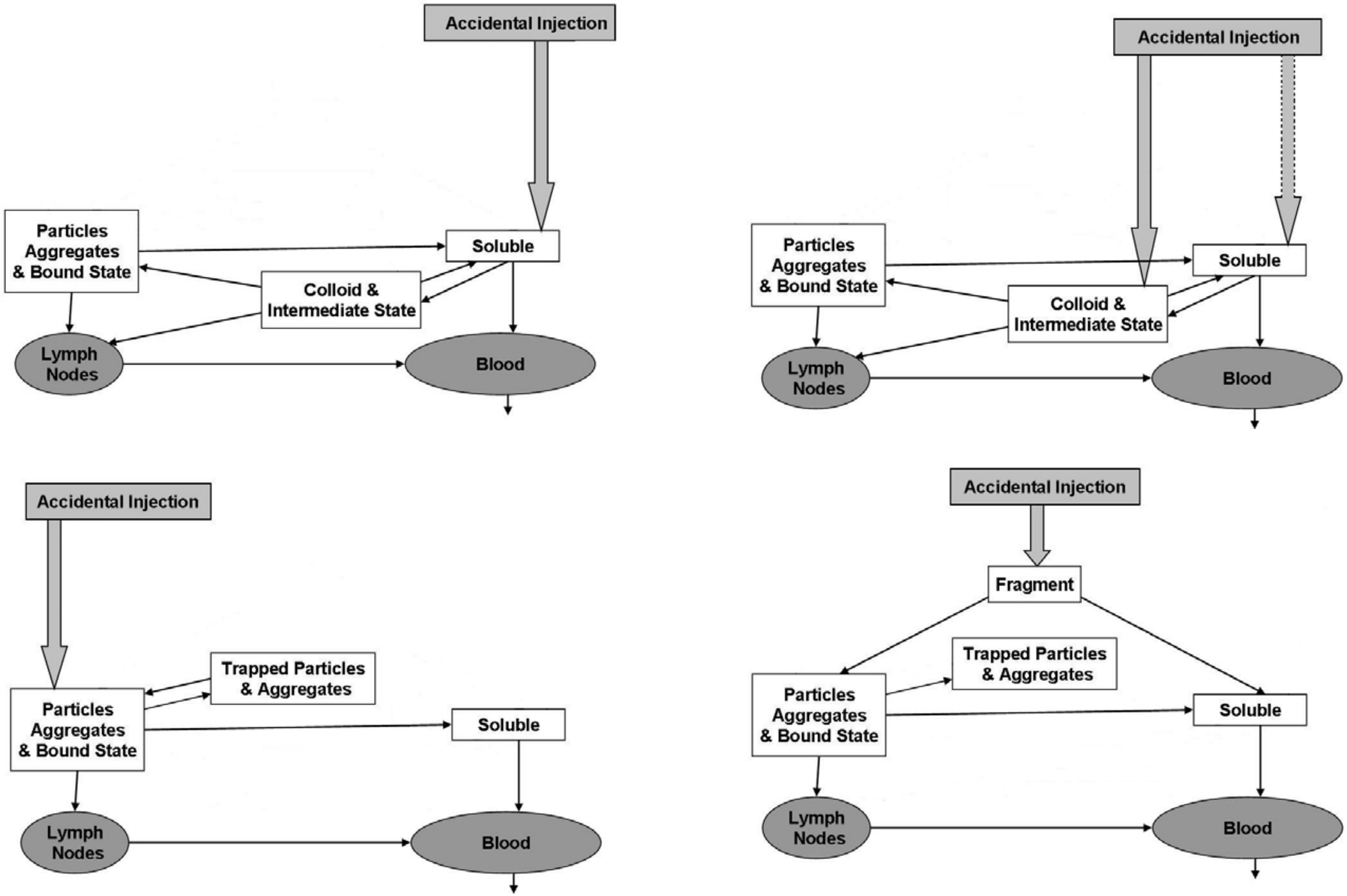


- Transfer of the material between compartments is characterized using first-order rate constants which were <u>empirically found</u>

The Complexity of the Model

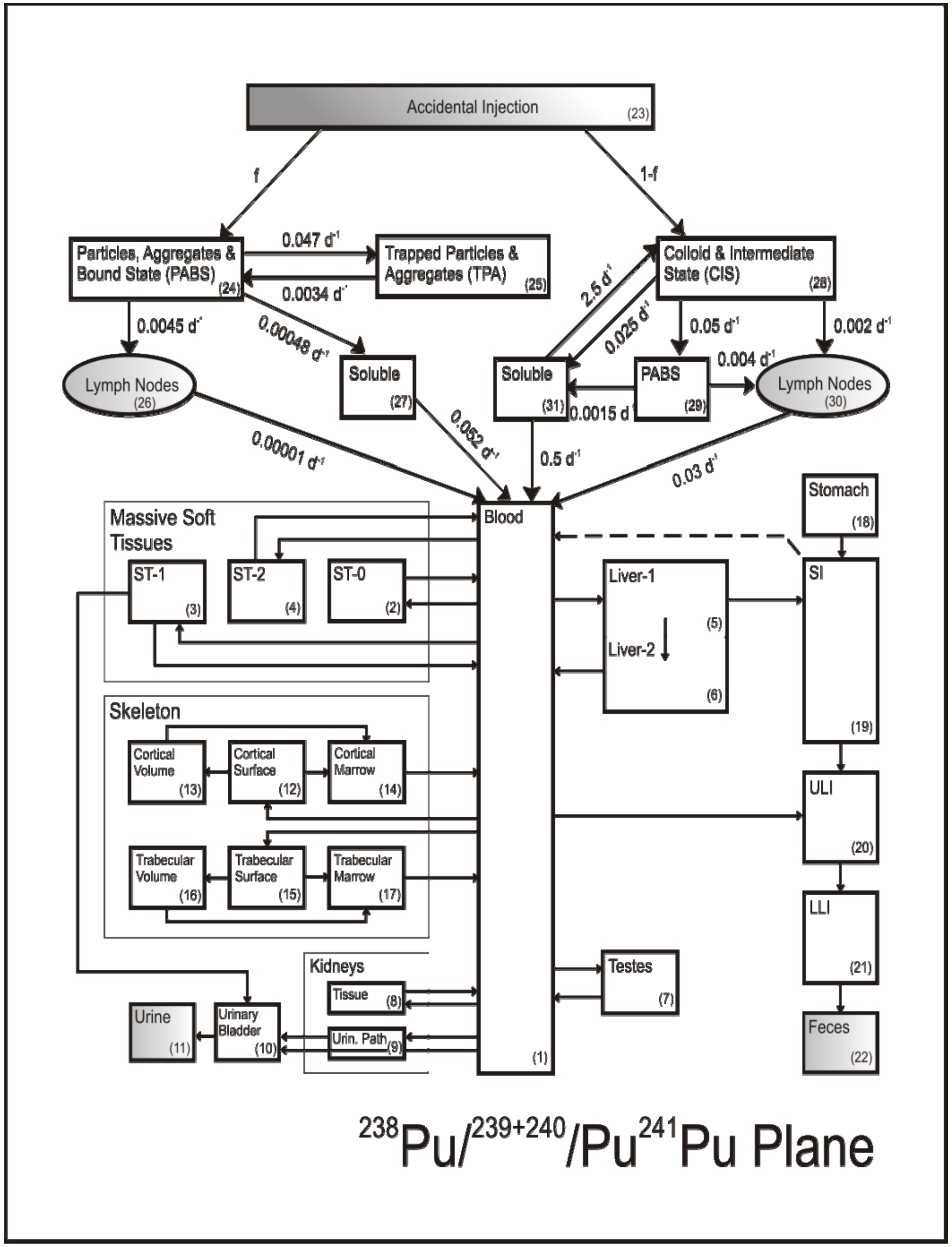
- The structure adopted in this model is reasonable from phenomenologic and mechanistic perspectives
- There is no data available that allows these compartments to be evaluated independently
- However, for a given radionuclide only a portion of the wound model is used (usually three compartments)

Portions of the Wound Model used for soluble, colloid, particulate and fragment forms of the radionuclide



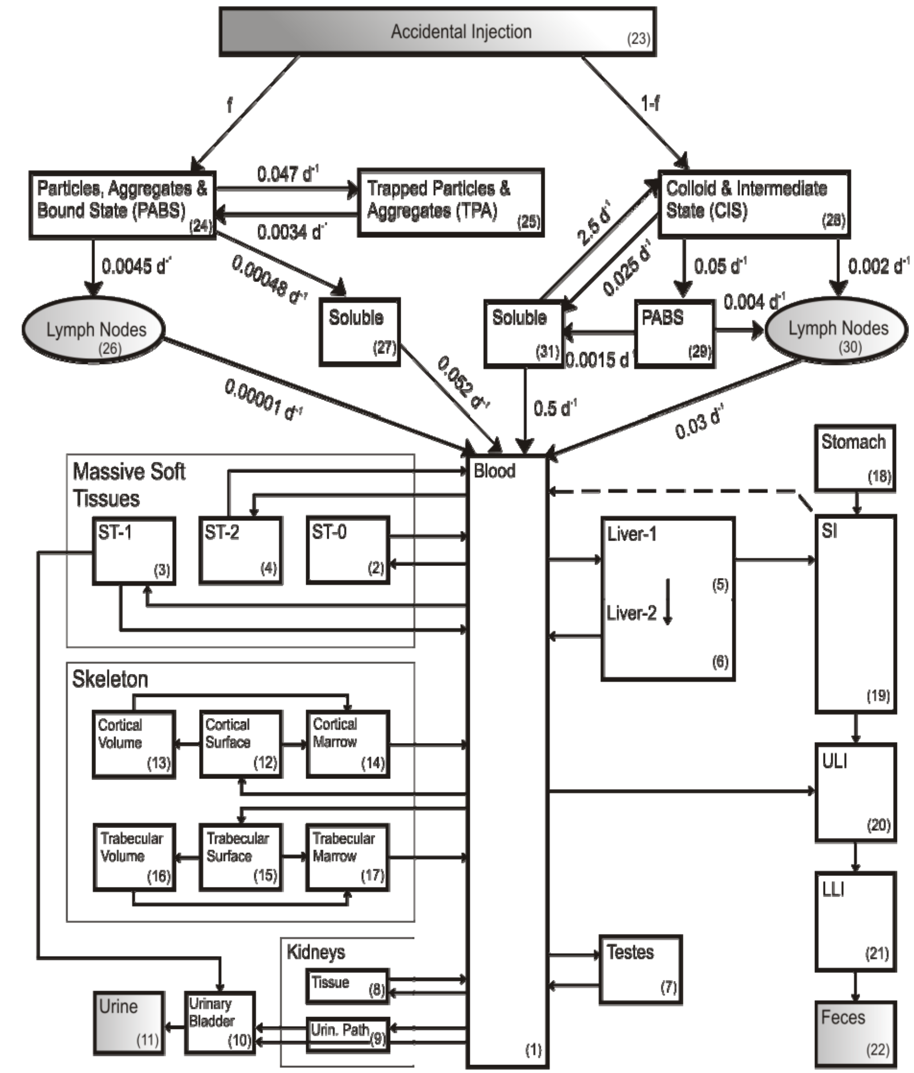
New Wound Model and Pu Systemic Model

- When Pu solution enters the wound site, it separates between PABS and CIS compartments
- We need to find fractionation between these two compartments



What I have done

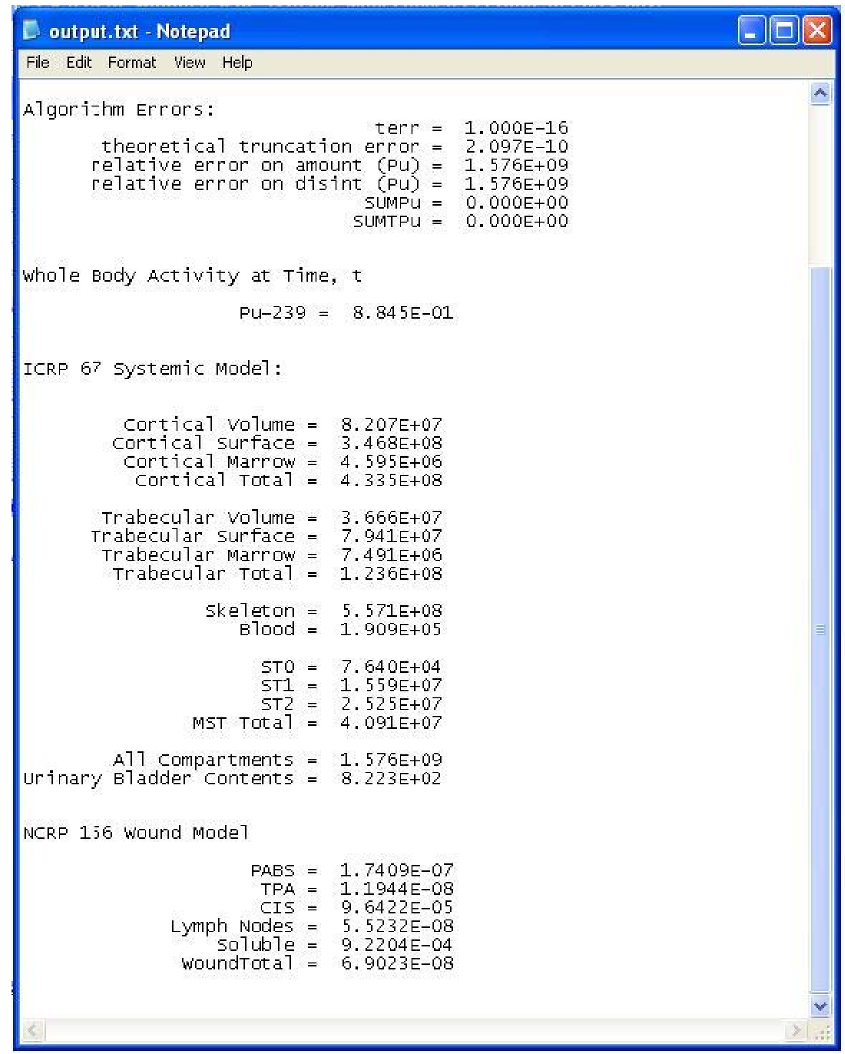
- I assumed 1Bq total intake (f = 50%)
- The values of transfer coefficients were taken from NCRP 156 default values
- Calculate number of atoms in each compartment, number of transformations, activity after 50 years



$^{238}Pu/^{239+240}Pu/^{241}Pu$ Plane

Results

- This is the section from the output file after executing powerbasic code
- Total activity is calculated by summing the activities in each compartment, minus the activity in the urine and feces compartments



output.txt - Notepad

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```
Algorithm Errors:
                                     terr =  1.000E-16
       theoretical truncation error =  2.097E-10
      relative error on amount (Pu) =  1.576E+09
      relative error on disint (Pu) =  1.576E+09
                                    SUMPu =  0.000E+00
                                   SUMTPu =  0.000E+00

Whole Body Activity at Time, t

                   Pu-239 =  8.845E-01

ICRP 67 Systemic Model:

          Cortical Volume =  8.207E+07
         Cortical Surface =  3.468E+08
          Cortical Marrow =  4.595E+06
           Cortical Total =  4.335E+08

        Trabecular Volume =  3.666E+07
       Trabecular Surface =  7.941E+07
        Trabecular Marrow =  7.491E+06
         Trabecular Total =  1.236E+08

                 Skeleton =  5.571E+08
                    Blood =  1.909E+05

                      ST0 =  7.640E+04
                      ST1 =  1.559E+07
                      ST2 =  2.525E+07
                MST Total =  4.091E+07

         All Compartments =  1.576E+09
Urinary Bladder Contents =  8.223E+02

NCRP 156 Wound Model

                     PABS =  1.7409E-07
                      TPA =  1.1944E-08
                      CIS =  9.6422E-05
              Lymph Nodes =  5.5232E-08
                  Soluble =  9.2204E-04
               WoundTotal =  6.9023E-08
```

Future Goals

- Estimate the fractionation coefficient
- Account for human data (first from Case 262) in PBCC code to estimate and optimize transfer coefficients for the new wound model and compare with the existing data
- Make appropriate suggestions for existing default transfer coefficients

References:

- A. C. James, L. B. Sasser, D. B. Stuit, T. G. Wood, S. E. Glover, T. P. Lynch and G. E. Dagle *USTUR Whole Body Case 0262: 33-Y Follow-up of* PuO_2 *in a Skin Wound and Associated Auxiliary Node,* Radiation Protection Dosimetry (2007), pp. 1–6
- Development of a Biokinetic Model for Radionuclide-Contaminated Wounds and Procedures for their Assessment, Dosimetry and Treatment, NCRP report no.156
- R.A. Guilmette, P.W. Durbin Scientific Basis for the Development of Biokinetic Models for Radionuclide-Contaminated Wounds Rad. Prot. Dosimetry Vol. 105, No 1-4, pp. 213-218 (2003)