

Evaluation of the NCRP wound model using USTUR plutonium-contaminated wound cases

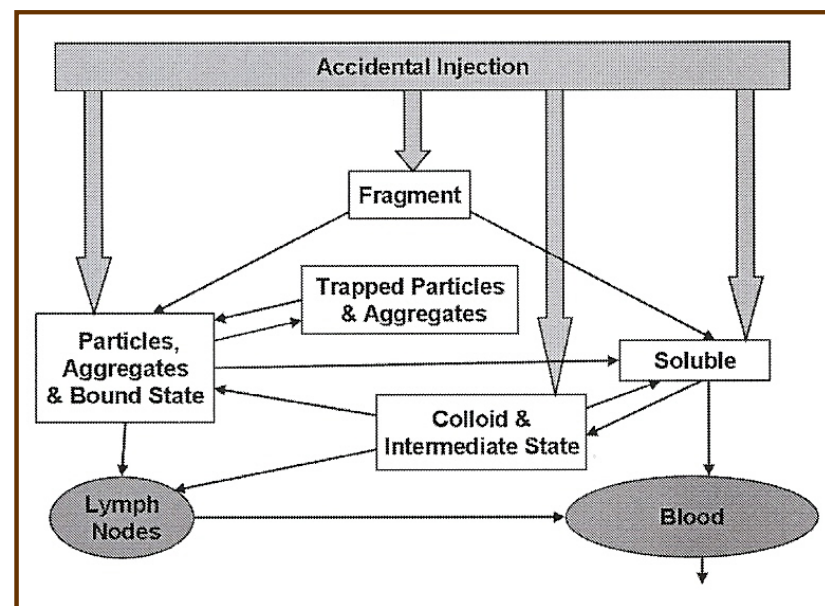
Liesl Germann
2008 Annual SAC Meeting
May 9, 2008



NCRP Report No. 156 – Wound Model

“Development of a Biokinetic Model for Radionuclide-Contaminated Wounds for Their Assessment, Dosimetry and Treatment” (2007)

- First formal attempt to develop a conceptual model of the pathways involved in radionuclide retention in a wound and the associated lymph nodes
- Overall wound retention predicted by equivalent sums of exponential retention functions
- Recommended default parameter values characterize retention and systemic uptake – derived from experimental animal data
- Emphasis on solution chemistry
 - 4 solution categories - weak, moderate, strong, avid
 - colloid category
 - 2 solid categories - particle, fragment



The NCRP biokinetic model of radionuclide translocation from a wound site as published in NCRP Report No. 156 (2007).

USTUR Case Applications

- Much of the data that contributed to the formulation of the NCRP wound model's retention coefficients originated from animal experiments and has been extrapolated to humans
- Specific tests of its applicability to the human metabolic system are needed
- USTUR wound cases allow testing of default retention parameters using real-life worker wound incidents

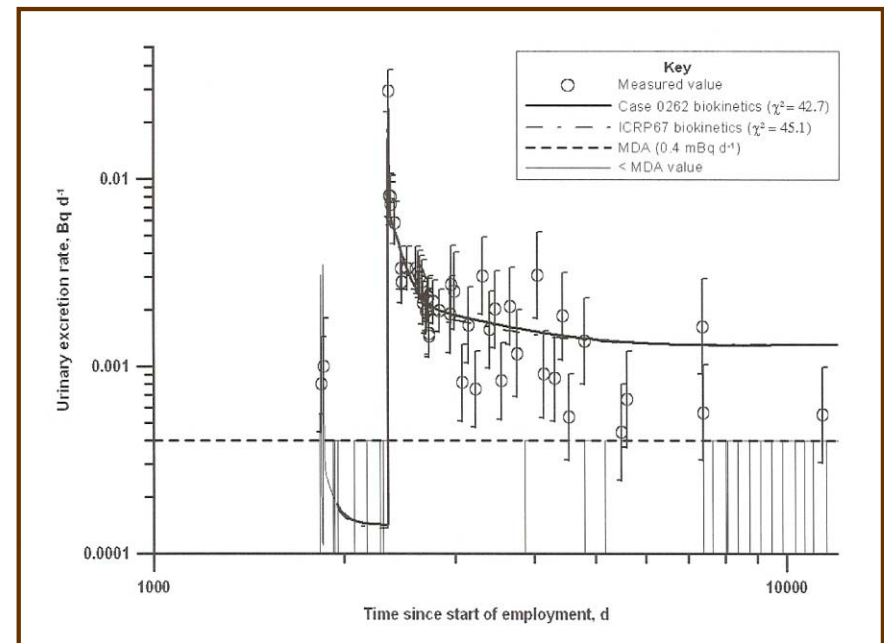
Especially plutonium cases:

- many plutonium-contaminated wound cases
- variety of wound types
- variety of plutonium mixtures



USTUR Case 0262 – James et al. (2008)

- Pu puncture wound to the skin of the thumb obtained while working with Pu materials in a glovebox
- Absorption rate constants were determined iteratively - optimum fit obtained ($\sum\chi^2 = 42.7$)
- 40% of the Pu initially deposited in the skin wound was absorbed slowly over the 33 years following the accident - other 14% was absorbed quite rapidly
- Mixture of insoluble $^{239}\text{PuO}_2$, and a more soluble Pu form



Optimum fit to the urinary excretion data for USTUR Case 0262 obtained by James et al. (2008).

USTUR Case 0262 – Poster Study

IR1 = weak

IR2 = moderate

IR3 = strong

IR4 = avid

IR5 = particle

IR6 = fragment

Save
 Quick Save

INTAKES

IR1	<input type="text" value="3.675E-02"/>	Bq
IR2	<input type="text" value="7.961E-05"/>	Bq
IR3	<input type="text" value="2.945E+01"/>	Bq
IR4	<input type="text" value="8.079E+00"/>	Bq
IR5	<input type="text" value="1.212E+00"/>	Bq
IR6	<input type="text" value="1.209E+02"/>	Bq

Statistics

Chi Square | Autocorrelation

	Chi-square	P		Chi-square	P
Whole body	<input type="text" value="7.08E-04"/>	<input type="text" value="1.00E+00"/>	Blood	<input type="text"/>	<input type="text"/>
Lungs	<input type="text"/>	<input type="text"/>	Thyroid	<input type="text"/>	<input type="text"/>
Urine	<input type="text" value="5.17E+01"/>	<input type="text" value="1.70E-01"/>	Liver	<input type="text"/>	<input type="text"/>
Feces	<input type="text"/>	<input type="text"/>	User Defined	<input type="text"/>	<input type="text"/>

Total Chi Square:
 Probability (P):
 Degrees of freedom:

The Chi squares for each bioassay quantity are given above. Given that the model is correct, the probability (P) of obtaining a value of Chi-square greater than the one observed here, is also calculated. Values of P less than some chosen level of significance (eg 5%) imply that the fit is not adequate.

Key

☐ (P<0.05)

☐ (P>0.05)

Fitted apportionment of NCRP wound absorption categories from Case 0262 data, and the resulting statistical parameters.

USTUR Case 0262 – NCRP Study

IR1 = strong

IR2 = avid

IR3 = fragment

The screenshot displays the USTUR software interface. On the left, the 'INTAKES' section lists three intake rates (IR1, IR2, IR3) in Bq. On the right, the 'Statistics' window is open, showing Chi-square and P values for various bioassay quantities. The 'Total Chi Square' is 4.65E+01, and the 'Probability (P)' is 3.71E-01. A key at the bottom indicates that red boxes represent P < 0.05 and green boxes represent P > 0.05.

INTAKES	
IR1	2.771E+01 Bq
IR2	1.450E+00 Bq
IR3	1.236E+02 Bq

Statistics			
Chi Square		Autocorrelation	
	Chi-square	P	
Whole body	1.20E-03	9.99E-01	Blood
Lungs			Thyroid
Urine	4.65E+01	3.31E-01	Liver
Feces			User Defined

Total Chi Square: 4.65E+01
Probability (P): 3.71E-01
Degrees of freedom: 44

The Chi squares for each bioassay quantity are given above. Given that the model is correct, the probability (P) of obtaining a value of Chi-square greater than the one observed here, is also calculated. Values of P less than some chosen level of significance (eg 5%) imply that the fit is not adequate.

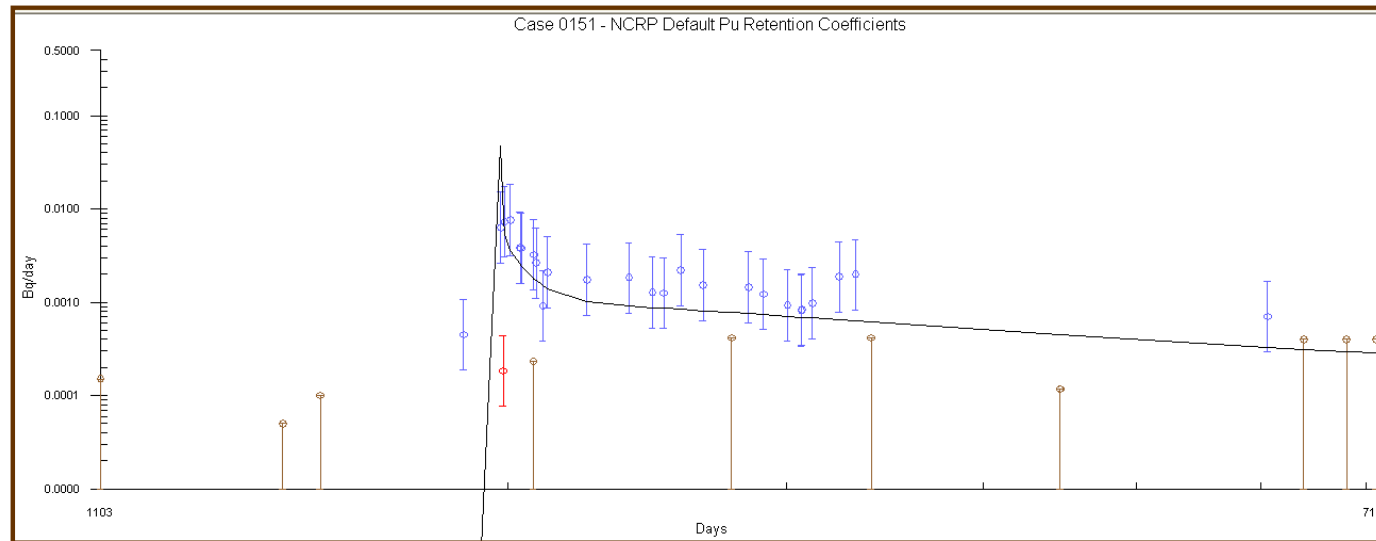
Key
Red box (P < 0.05) Green box (P > 0.05)

Fitted apportionment of NCRP plutonium wound absorption categories for the optimized fit from Case 0262 data, and the resulting statistical parameters.

USTUR Case 0262 – Comparisons

- Very similar chi-squares obtained in best fit solutions
 - Iteration $X^2 = 46.5$
 - NCRP $X^2 = 42.7$
- Autocorrelation statistically significant in both analyses
- Small soluble component indicated in both analyses
 - James et al. – 14% soluble
 - NCRP study – strong and avid categories represented
- Not all plutonium mixtures are represented by the NCRP default retention coefficients:
 - the Pu compound involved in the Hanford incident was likely NOT fragment
 - the fragment category received the greatest apportionment
 - the particle category received insignificant apportionment
 - indicates that a slower particle retention coefficient is needed

USTUR Case 0151



- Plutonium intake in 1950s from puncture wound on left ring finger acquired while working in a process hood at Hanford
- Statistically significant fit ($\sum\chi^2 = 16.$) – all 4 categories required to obtain minimum chi-square
- Autocorrelation coefficient not significant
- Apportionment of NCRP wound absorption categories indicate that the Pu material was more soluble than the Case 0262 mixture

USTUR Case 0151

IR1 = strong

IR2 = avid

IR3 = particle

IR4 = fragment

The screenshot displays the 'INTAKES' and 'Statistics' windows of a software application. The 'INTAKES' window on the left lists four intake categories (IR1 to IR4) with their respective values in Bq. The 'Statistics' window on the right shows the 'Chi Square' tab, which contains a table of Chi-square and P values for various bioassay quantities. The 'Total Chi Square' is 1.62E+01, and the 'Probability (P)' is 8.46E-01. A key at the bottom indicates that red boxes represent P < 0.05 and green boxes represent P > 0.05.

INTAKES		
IR1	1.851E+01	Bq
IR2	1.255E-02	Bq
IR3	2.209E-04	Bq
IR4	1.430E-03	Bq

Statistics					
Chi Square		Autocorrelation			
	Chi-square	P		Chi-square	P
Whole body			Blood		
Lungs			Thyroid		
Urine	1.62E+01	8.46E-01	Liver		
Feces			User Defined		

Total Chi Square: 1.62E+01
Probability (P): 8.46E-01
Degrees of freedom: 23

The Chi squares for each bioassay quantity are given above. Given that the model is correct, the probability (P) of obtaining a value of Chi-square greater than the one observed here, is also calculated. Values of P less than some chosen level of significance (eg 5%) imply that the fit is not adequate.

Key
[Red Box] (P<0.05) [Green Box] (P>0.05)

Fitted apportionment of NCRP plutonium wound absorption categories from Case 0151 data, and the resulting statistical parameters.

Summary

The U.S. Transuranium & Uranium Registries provide real cases of plutonium-contaminated wounds with which to test the ability of the new NCRP Report No. 156 wound model's default retention parameters to predict systemic plutonium uptake in the human metabolic system.

Continuing Work:

- Search for additional Pu intake cases free from confounding factors:
 - Inhalations
 - Chelations
 - Additional wounds
- Application of various combinations of the NCRP recommended default retention coefficients for Pu chemistry
- Optimum fit to the bioassay data that minimizes chi-square and autocorrelation coefficient

References

- Germann LK, Brey RR, James AC and Guilmette RA. Evaluation of the in press NCRP wound model using USTUR case 0262 data. Poster presented at the 52nd Annual Meeting of the Health Physics Society, 2007. Available online at: <http://www.ustur.wsu.edu/GraduateProjects/GradProjects.html>.
- Guilmette RA and Durbin PW. Scientific basis for the development of biokinetic models for radionuclide-contaminated wounds. *Radiat Prot Dosim* 105:213-218; 2003.
- Guilmette RA, Durbin PW, Toohey RE and Bertelli L. The NCRP wound model: Development and application. *Radiat Prot Dosim*; 2007.
- International Commission on Radiological Protection. Age-dependent dose to members of the public from intake of radionuclides: Part 2, ingestion dose coefficients. ICRP Publication 67. *Ann ICRP* 23:(3-4); 1993.
- International Commission on Radiological Protection. Human respiratory tract model for radiological protection. ICRP Publication 66. *Ann ICRP* 24:(1-3); 1994.
- James AC, Birchall A, Marsh JW, and Puncher M. User manual for IMBA Expert™ USDOE-Edition (Phase II). Richland, WA: ACJ & Associates, Inc.; 2004.
- James AC, Sasser LB, Stuit DB, Wood TG, Glover SE, Lynch TP and Dagle GE. USTUR whole body case 0262: 33-y follow-up of PuO₂ in a skin wound and associated lymph node. *Radiat Prot Dosim*; 2008.
- National Council on Radiation Protection and Measurements. Development of a biokinetic model for radionuclide-contaminated wounds and procedures for their assessment, dosimetry and treatment. Bethesda: National Council on Radiation Protection and Measurements; NCRP Report No. 156; 2007.
- Puncher M, Birchall A and Marsh JW. The autocorrelation coefficient as a tool for assessing goodness of fit between bioassay predictions and measurement data. Presented at the International Workshop on 'Internal Dosimetry of Radionuclides' Montpellier, France, 2-5 October 2006.