Document Title:	Document Number: ORAUT-OTIB-0022
Guidance on Wound Modeling for Internal Dose Reconstruction	Revision: 00 Effective Date: 11/18/2005 Type of Document: OTIB Supersedes: None

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☒ New ☐ Total Rewrite ☐ Revision ☐ Page Change

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
11/18/2005	00	New technical information bulletin to provide information and guidance to Oak Ridge Associated Universities (ORAU) Team Dose Reconstructors regarding the best estimate of internal dose from a contaminated wound. First approved issue. Training required: As determined by the Task Manager. Initiated by Elizabeth M. Brackett.

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1.0 PURPOSE

The purpose of this technical information bulletin (TIB) is to provide information and guidance to dose reconstructors regarding the best estimate of internal dose from a contaminated wound.

Technical information bulletins (TIBs) are general working documents that provide guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained. TIBs may be used to assist the National Institute for Occupational Safety and Health in the completion of individual dose reconstructions.

2.0 IN THIS DOCUMENT THE WORD "FACILITY" IS USED AS A GENERAL TERM FOR AN AREA, BUILDING, OR GROUP OF BUILDINGS THAT SERVED A SPECIFIC PURPOSE AT A SITE. IT DOES NOT NECESSARILY CONNOTE AN "ATOMIC WEAPONS EMPLOYER FACILITY" OR A "DEPARTMENT OF ENERGY FACILITY" AS DEFINED IN THE ENERGY EMPLOYEES OCCUPATIONAL ILLNESS COMPENSATION PROGRAM ACT OF 2000 [42 U.S.C. SECTIONS 7384L(5) AND (12)].BACKGROUND

This discussion focuses on how to use the Integrated Modules for Bioassay Analysis (IMBA) computer program to evaluate intakes of plutonium by wound. The National Council on Radiation Protection and Measurements (NCRP) is currently working on a generic wound model (Guilmette and Durbin 2003; Durbin 2003), but that model is not yet available for general use. The approach suggested herein is based on experience with plutonium and is consistent with the information currently available on the NCRP wound model.

3.0 WOUND MODELING

3.1 BEHAVIOR OF PLUTONIUM IN A WOUND

When plutonium is introduced into the body via a wound, four things can happen to the plutonium, assuming there is no medical intervention:

- The plutonium can be *absorbed* from the wound into the bloodstream.
- The plutonium can be *transported* from the wound to the lymphatic system. The classic example of this is the transport of plutonium from a wound on the hand to the axillary lymph nodes (in the armpit). This plutonium (and associated ^{241}Am) can be detected in a chest count and be improperly read as a lung deposition (Sharma et al. 1997).
- The plutonium can be *retained* in the tissue in the vicinity of the wound.
- The plutonium can be *removed* from the wound to the environment by natural processes (e.g., when a scab falls off the wound).

Ideally, assuming that the isotopic composition of the plutonium is known and that we can compensate for attenuation of photons in the tissue and in the plutonium, a wound count performed immediately after the accident would show the total plutonium deposited in the wound. Repeated measurements over time would show that the quantity of plutonium in the wound is decreasing in a multiple exponential fashion as material is absorbed, transported, and removed. However, the wound count cannot tell what fraction of the deposition is going where.

From a dosimetric perspective, the plutonium retained in the wound and removed from it are of negligible significance unless a cancer develops at the wound site, which is rare. The plutonium transported to the lymphatic system is of dosimetric significance if the plutonium dissolves in the lymph nodes and is absorbed into the bloodstream or if a cancer develops at the site of the lymph nodes. To compound the problem, there are no standard models for calculating the dose to the wound site or the lymph nodes; IMBA therefore does not calculate the dose to the wound site or lymph nodes such as the axillary lymph nodes. For this reason, the dose to the wound site and lymph nodes associated with the wound will be ignored unless a cancer develops at one of those sites. In such a case, a custom dose calculation will be necessary.

3.2 SUGGESTED WOUND MODEL

In most cases, the fraction of the deposition absorbed from the wound site into the bloodstream is the most important dosimetrically because it will be metabolized as if it had been absorbed from the lung or gastrointestinal tract. This means that standard models (and IMBA) can be used to evaluate urinary excretion and calculate the dose to the systemic organs following an uptake via a wound. The urinary excretion resulting from a wound often exhibits a pattern consistent with two single exponential feed compartments; one with a relatively short half-life, on the order of 1 day, and one with a relatively longer half-life, on the order of hundreds of days. As a starting point, the following absorption model is suggested:

$$R_{wou}(t) = 0.9\,e^{\frac{-\ln(2)}{1day}t} + 0.1e^{\frac{-\ln(2)}{150\,days}t} \qquad (1)$$

where $R_{wou}(t)$ is the fraction retention of the plutonium in the wound assuming no radioactive decay and t is the time since the wound occurred. These parameters are entered into the user-defined wound model of IMBA as shown in Figure 3-1.

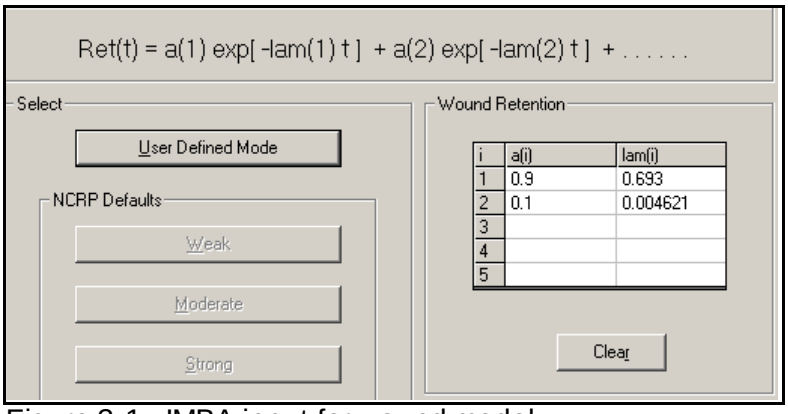

Figure 3-1. IMBA input for wound model.

The coefficients and rate constants can be modified to produce a better fit to the observed urinary excretion. Additional terms can be added, but this is seldom necessary. If an individual has had more than one intake via a wound, individual models can be entered by clicking “Advanced” on the tool bar on the main page and deselecting “Apply Model Params to All IRs.”

This approach provides only the fraction of the total wound deposition that is absorbed into the bloodstream. As a result the initial wound deposition measured by in-vivo methods is likely to be greater than the wound deposition calculated with the urine data because of insoluble material

present in the wound. Because the soluble fraction of the initial deposition is usually the most important dosimetrically, greater weight should be given to the initial wound deposition calculated from urinary excretion. Any plutonium absorbed from material transported to the lymph nodes will likely be accounted for in the long-term component of the wound model.

3.3 MEDICAL INTERVENTION

Medical intervention frequently occurs after wound depositions because of the high doses to systemic organs that can result and because physicians can typically take action to reduce the dose. That "action" is chelation therapy and/or the excision of contaminated tissue from the wound. Chelation therapy consists of the injection or inhalation of a chelating agent or the introduction of the chelating agent directly into the wound site. A chelation agent is a chemical compound that binds to the plutonium atom and alters its chemical properties so that it is rapidly excreted rather than deposited in systemic organs, which results in a reduction of dose to systemic organs and tissues.

The usual approach to evaluating urinary excretion after chelation therapy is to model only the urinary excretion observed more than 100 days after the last administration of the chelation agent (Jech et al. 1972). Other, more complex approaches (LaBone 2002) can be used if necessary, but they are not discussed herein.

The excision of contaminated tissue from the wound site creates a discontinuity in the source term. For example, assume that 1 nCi of plutonium is deposited in a wound and the processes described above promptly begin to translocate it from the wound. If the physician excises 0.5 nCi of plutonium from the wound a day later, there is a sudden reduction in the quantity of plutonium in the wound. This reduction is equivalent to a negative intake and can be difficult to model. One approach is to simply ignore the urinary excretion data prior to the excision and model the data observed afterwards. This often works well because excisions are usually performed within days of the wound event.

3.4 EXAMPLE

An individual had two major incidents that resulted in contaminated wounds. The first is at t=0 day and the second at t=367 days. Both wounds were evaluated with the default model, using a maximum likelihood fit with square root errors in IMBA. This results in intakes of 715 dpm for the first wound and 13,000 dpm for the second. The IMBA plot is shown in Figure 3-2.

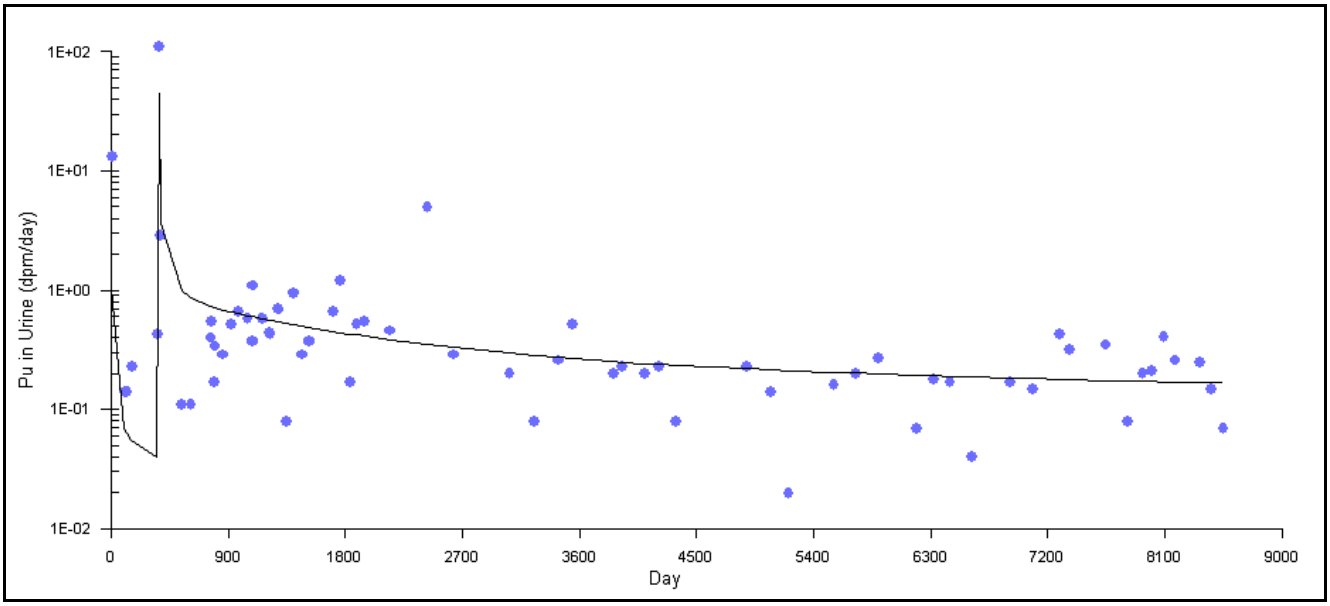

Figure 3-2. IMBA plot for initial fit to example wound case.

Tissue was excised from the wound after the second incident. The fit to the first intake is improved by reducing the errors associated with the first five data points. A value of 0.5 was assigned to *k* for the first five data points versus a *k* of 1.0 for the rest of the results. The fit in Figure 3-3 was produced.

The intakes are now estimated at 4,300 dpm for the first intake and 10,890 dpm for the second. Note that the total intake (the sum of the two) does not change significantly when we force the first intake to be higher, but this fit will result in the person receiving the dose sooner than determined from the first fit. Finally, it is interesting to note that this individual had measurable quantities of ^{241}Am in the area of the wounds and in his chest (is the activity in the lymph nodes or lungs?) 20 years after these incidents. This raises the question of whether an inhalation intake should be assigned to this individual sometime during his work history? Because he has a cancer of a systemic organ, an additional inhalation intake of an insoluble material would add little additional dose. If he had cancer of the respiratory tract, the possibility of an inhalation intake would become more important. In this case the claimant-favorable approach would be to assign an inhalation intake that was consistent with the other available data.

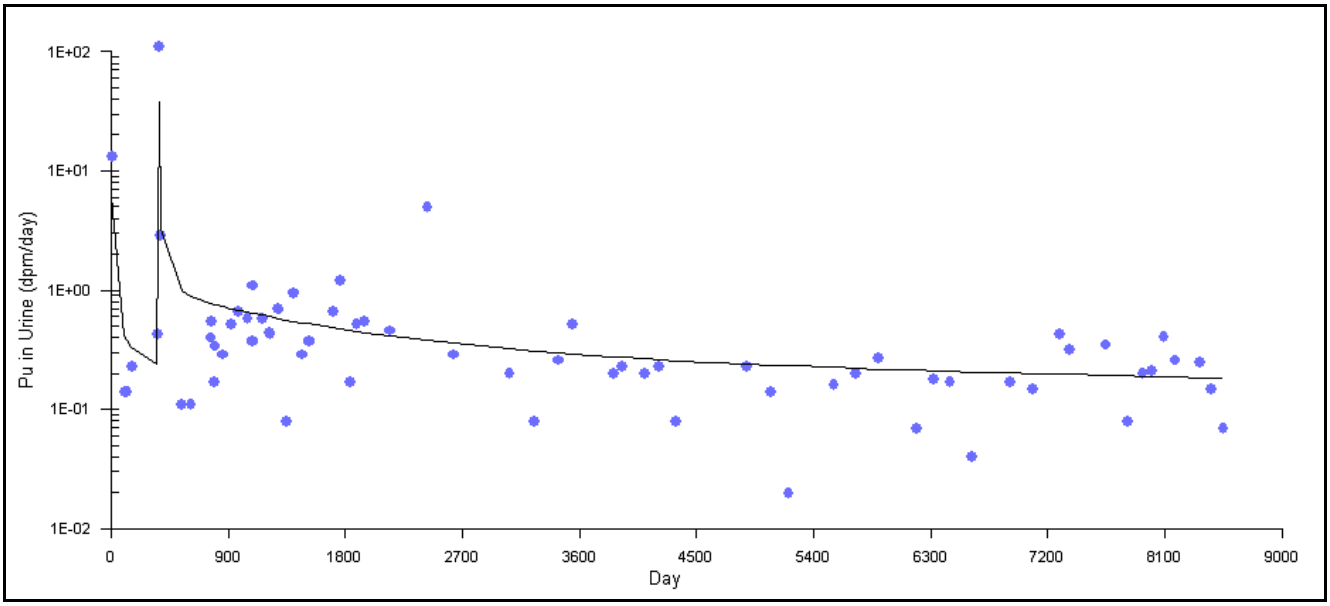

Figure 3-3. IMBA plot for modified fit to example wound case.

3.5 OTHER RADIONUCLIDES

The general approach illustrated here with plutonium may be applied to other radionuclides. First, model the urinary excretion using a single feed compartment with a short half-life to simulate a wound with instantaneous uptake to the blood. If the shape of the curve does not adequately fit the observed urinary excretion, the half-life of the short-lived compartment can be increased and a second long-lived feed compartment added.

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