THE NCRP WOUND MODEL:
DEVELOPMENT AND APPLICATION

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Learning Objectives

• Describe the structure and use of the NCRP Wound Model
• Identify sources for wound model dose coefficients and retention factors
NEED FOR A WOUND MODEL

- Wounds relatively common in specialized plants in U.S.A. and Russia
  - 136 Pu wounds at Hanford by 1969
  - 429 Pu wounds at Rocky Flats Plant by 1967
  - 248 wounds at Mayak PA by 1994

- Relatively little reported biokinetic information on untreated workers in literature

- Can expect more wounds from decommissioning activities
PERSIAN GULF WAR AND DU

• “Friendly Fire” incidents involving DU (depleted uranium) penetrators and armored vehicles
• 39 soldiers on long-term follow up for DU contamination (12 in high DU group)
• Questions about the dosimetry and risk from embedded DU fragments
RADIOGRAPH OF VETERAN WITH EMBEDDED DU FRAGMENTS
DU FRAGMENT REMOVED SURGICALLY
STRATEGY FOR WOUND MODEL DESIGN

• Scientifically and mechanistically based
• Can extrapolate to elements without data
• Can couple to systemic models for bioassay
• Pragmatic and easy to implement

DESIGN BASIS

• Source characteristics
  – Physical
  – Chemical
• Wound characteristics
  – Foreign body reaction
DEVELOPMENT OF DEFAULT CATEGORIES FOR SOLUBLE RADIONUCLIDES IN WOUNDS

• Data from 48 radionuclides injected as initially soluble radionuclides (mostly from studies at Crocker Labs, now LBNL)

• Retention classified according to chemical properties
  – Tendency for hydrolysis
  – Relationship with solubility product $K_{sp}$ (depends on chemical, pH, concentration/mass)

• In general, retention roughly proportional to hydrolysis potential
  – $1^- < 1^+ < 2^+ < 3^+ < 4^+$
CATEGORIES OF WOUND RETENTION FOR SOLUBLE RADIONUCLIDES

• Weakly retained
  – Simple anions (I), oxo- and chloro-anions (Sb, Tc, As, W, Sb)
  – Monovalent cations (Rb, Cs)
  – Divalent cations (Ca, Sr, Ba, UO$_2^{2+}$)

• Moderately retained
  – Chemical analogs of above
  – Ag, Ra, V, Te, Os, Pt
CATEGORIES (continued)

• Strongly retained
  – Trivalent cations (Y, La, Ga, In, Cr, Nb)
  – Trivalent lanthanides
  – Ac, Pu (small masses < 0.2 µg), Am, Cm
  – Be, Po

• Avidly retained
  – Tetravalent cations (Zr, Sn, Th, Pu > 10 µg)
  – Pentavalent Pa
DEFAULT RETENTION GROUPS FOR SOLUBLE RADIONUCLIDES IN WOUNDS

Fraction Retained in Wound (%) vs. Time after Injection (days)

- Weak
- Moderate
- Strong
- Avid

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Graph showing the fraction of radionuclides retained in wounds over time.
COMPARTMENTAL MODEL OF STRONG DATA

Fractional Retention (%)

Time after Injection (days)
BIOKINETICS OF RADIOACTIVE PARTICLES AND FRAGMENTS

• Few studies provide useful data for modeling
  – PuO$_2$ particles in rats (*Harrison et al. 1978*)
    • Avid retention - 97% at 28 d
  – Polymeric Pu in rats and mice (*Brues et al. 1965*)
    • Avid retention – 80% at 6 mo
  – PuO$_2$ in dogs (*Bistline 1973*)
  – Pu metal wire in rats and rabbits (*Lisco and Kisieleski 1953*)
    • Wire rapidly disintegrated into fragments
    • Accompanied by significant tissue reaction
  – DU fragments in rats (*Hahn et al. 2001*)
    • Fragments corroded and disintegrated with time
RETENTION OF COLLOIDAL Pu NITRATE IN DOGS (data from Bistline 1973)
MODEL FIT OF AIR-OXIDIZED Pu PARTICLES IN DOGS (CSU)

Fractional Retention (%) vs. Time after Injection (days)

- LN Data
- Systemic Data
- Wound Data
- Particles
- Trapped Particles

Time after Injection (days):
0 50 100 150 200 250 300 350 400
DU METAL FRAGMENTS IMPLANTED IN RAT MUSCLE
APPLICATION OF WOUND MODEL TO BIOASSAY INTERPRETATION

• Select $^{238}$U and three relevant default categories
• Couple wound model to ICRP 69 systemic biokinetic model
• Solve using AIDE dose assessment software (v.4; Bertelli)
U RETENTION IN WOUND SITE
U RETENTION IN KIDNEY

![Graph showing kidney content over time for different forms: Weak, Particle, Fragment.](image)
U EXCRETION IN URINE
SUMMARY AND CONCLUSIONS

• Wound model describes radionuclide behavior for:
  – Range of physical and chemical forms
  – Large number (48) of solubles
  – Fewer (4) insolubles
• Sound scientific basis in chemistry and biology
• Easy to use for bioassay interpretation
• Model proposed by INDOS/DOCAL for implementation in ICRP revision of occupation guidance on radiation protection from intakes of radionuclides
• Model report published as NCRP report 156 (2006)
Follow-on Tasks

• The Radiation Emergency Assistance Center/Training Site (REAC/TS) at ORISE has coupled the NCRP wound model to the ICRP biokinetic models for other elements to generate dose coefficients and intake retention/excretion factors.

• Data for 38 selected radionuclides were published in the May 2011 issue of Health Physics journal (Toohey et al., Health Phys. 100(5), 508-514, 2011.)

• Complete data tables are available online at http://orise.orau.gov/reacts/resources/retention-intake-publication.aspx