ICRP Systemic Biokinetic Models
Learning Objectives

• Describe the parameters and uses of systemic biokinetic models
• Identify sources for various models
• Explain differences between the ICRP and NRC models for uranium
Systemic biokinetic models

- Element-specific
- Available in ICRP 78 (1997) for H, Fe, Co, Sr, Ru, I, Cs, Ra, Th, U, Np, Pu, Am, Cm, Cf, and in earlier reports for other elements
- Give the systemic deposition of activity into each organ from the transfer compartment (blood and lymph)
- Give the transfer coefficients between the organs and the bloodstream
- Give excretion pathways and fractions
**Uptake**

- The fraction of an intake entering the systemic circulation is referred to as the **uptake**.
- ICRP models for radionuclides in systemic circulation are used to calculate dose coefficients.
- Following review of data behavior of radionuclides in the body, a number of elemental models have been revised.
- Revised models were also used to calculate dose coefficients for workers.
Revision of systemic models

- Models for several elements have been revised, particularly to account for recycling of radionuclides between compartments (so they are more complicated!)

- The models are more physiologically oriented, can be applied to calculate bioassay quantities, and evaluate dose to the general population not only to workers.

- Previously, a number of radionuclides (e.g. $^{239}$Pu) were assumed to be retained on bone surfaces - a conservative assumption

- Evidence indicates a fraction of plutonium is buried as a result of bone growth and turnover
Revision of systemic models, con’t.

- Another fraction is desorbed and re-enters the blood

- Some may be re-deposited in the skeleton and liver or be excreted

- In contrast, ‘bone volume seeking’ nuclides, such as $^{90}$Sr and $^{226}$Ra, have been assumed to instantaneously distribute in bone volume
Revision of systemic models, con’t.

- The process is actually progressive.
- Generic models for plutonium, other actinides, and for the alkaline earth metals have been developed to:
  - Allow for the known radionuclide behavior
  - Account for knowledge of bone physiology
- The model for alkaline earth metals has also been applied, with some modifications, to lead and to uranium.
GENERIC BIOKINETIC MODEL

INHALATION  EXHALATION

SKIN  LYMPH NODES  RESPIRATORY TRACT

INGESTION

WOUND  SUBCUTIS & MUSCLE  BLOOD AND ECF

GI TRACT

SWEAT

SKIN

LIVER

OTHER ORGANS

KIDNEY

URINARY BLADDER

URINE

FECES
**Iodine (from ICRP 67)**

- Of iodine that reaches the blood:
  - 30% is accumulated into the thyroid gland,
  - 70% is excreted directly in urine.

- Iodide incorporated into thyroid hormones leaves the gland with an half time of 80 d and enters other tissues where it is retained with a half-time of 12 d.

- Most iodide (80%) is subsequently released and is available in the circulation for uptake in the gland and urinary excretion.

- The remainder (20%) is excreted in faeces in organic form.
Iodine

• Model:

Figure 5.1. Structure of the model for iodine used in ICRP Publication 30 (1979) and current ICRP documents.
**Cesium** (from ICRP 67)

- Systemic caesium is taken to be distributed uniformly throughout all body tissues

- 10% of activity is assumed to be retained with a biological half life of 2 days (A)

- 90% of activity is assumed to be retained with a biological half life of 110 days (A)

- For female the half time of compartment B is significantly less than for males.

- In some countries there is also evidence of mean biological half time for adult males shorter than 110 d.

- Urinary to faecal excretion ratio of 4:1 is recommended.
Cesium

- Model:
Model for Sr, Ra and U
Model for Th, Np, Pu, Am and Cm
Radioactive progeny

- A number of radionuclides decay to nuclides that are themselves radioactive
- It has been assumed that the decay products would follow the biokinetics of their parents
- A few exceptions made for decay products which are isotopes of noble gases or iodine
- The revised biokinetiic models apply separate systemic biokinetics to the parent and its decay products for intakes of radioisotopes of lead, radium, thorium and uranium.
**Excretion**

- Urinary bladder and colon are given $w_T$ values
- Specific information is given on excretion pathways in the urine and feces in revised biokinetic models for workers.
- GI tract model is used to assess doses from systemic activity lost into the feces.
- Secretion of radionuclides from the blood into the upper large intestine is assumed (e.g. for bone-seeking radionuclides)
- A urinary bladder model has been adapted for calculating doses to the bladder wall

$$\lambda = 12 \text{ d}^{-1} \quad [6 \text{ voids d}^{-1}]$$