ORNL’s Support to Committee 2 in Implementation of ICRP 103

K. F. Eckerman
Oak Ridge National Laboratory

ISCORS Meeting
Oct 1, 2008
US Team

- R Leggett & K Eckerman – ORNL
- W. Bolch – U of Florida
- N Hertel – Georgia Tech

Access to graduate students

- L Bertelli – LANL
- R Guilmette - Lovelace
ICRP Recommendations

• 1959 ICRP Publication 1
• 1977 ICRP Publication 26
• 1991 ICRP Publication 60
• 2007 ICRP Publication 103

• New recommendation about every 16 y
• Committee 2 tasked with deriving operational quantities
Structure of ICRP

• Main Commission
  – Committee 1. Radiation Effects
  – Committee 2. Doses from Radiation Exposures
  – Committee 3. Protection in Medicine
  – Committee 4. Application of Recommendations
  – Committee 5. Protection of the Environment
• Technical work carried out in Task Groups and Working Parties
• Major Post Publication 107 effort within C2
Committee 2

• C2 Aug 25-28, 2008 St. Petersburg meeting

• Current Task Groups & Working Parties
  – DOCAL: Dose Calculational Task Group
    • Nuclear Decay Data
    • Reference Phantoms
    • Computational Software
  – INDOS: Internal Dosimetry Group
    • Biokinetic Models
  – Working Parties
    • Alpha epidemiology (w C1)
      – Radon
    • Publication 74, revised (joint w ICRU)
    • Space Radiation (ICRP report)
    • Use of Effective Dose (C2, C3, C4)

• Liaison activities with
  – ICRU: Various topics
  – NCRP: No active topics
DOCAL Task Group

- Formed in 1974
- Chair
  W S Synder to 1977  M R Ford to 1984
  K F Eckerman to 2004  W E Bolch 2004 -
Evolution not Revolution

In the new recommendations some things remain because they work.

explained because guidance needed

added because of a void

differ because knowledge evolved

“It may not be necessary to change regulations in those countries that have adopted Publication 60.” L-E Holm 2005.
**Principles of Radiation Protection**

**Justification:** action changing exposure of individuals to be justified in advance – positive net benefit

**Optimization:** exposures should be as low as reasonable achievable and below dose constraints

**Dose Limits:** unchanged from Publication 60

**Dose Constraints:** development of concept introduced in Publication 60
Radiation Weighting Factors

Table 2. Recommended radiation weighting factors.

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Radiation weighting factor, $w_R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photons</td>
<td>1</td>
</tr>
<tr>
<td>Electrons(^a) and muons</td>
<td>1</td>
</tr>
<tr>
<td>Protons and charged pions</td>
<td>2</td>
</tr>
<tr>
<td>Alpha particles, fission fragments, heavy ions</td>
<td>20</td>
</tr>
<tr>
<td>Neutrons</td>
<td>A continuous function of neutron energy (see Fig. 1 and Eq. 4.3)</td>
</tr>
</tbody>
</table>

All values relate to the radiation incident on the body or, for internal radiation sources, emitted from the incorporated radionuclide(s).

\(^a\) Note the special issue of Auger electrons discussed in paragraph 116 and in Section B.3.3 of Annex B.

\[
H_T = \sum_R w_R D_{T,R}
\]
Neutron Weighting Factors

\[ w_R = \begin{cases} 
2.5 + 18.2e^{-[\ln(E_n)]^2/6}, & E_n < 1 \text{ MeV} \\
5.0 + 17.0e^{-[\ln(2E_n)]^2/6}, & 1 \text{ MeV} \leq E_n \leq 50 \text{ MeV} \\
2.5 + 3.25e^{-[\ln(0.04E_n)]^2/6}, & E_n > 50 \text{ MeV}
\end{cases} \]
Tissue Weighting Factors

Table 3. Recommended tissue weighting factors.

<table>
<thead>
<tr>
<th>Tissue</th>
<th>$w_T$</th>
<th>$\sum w_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone-marrow (red), Colon, Lung, Stomach, Breast, Remainder tissues*</td>
<td>0.12</td>
<td>0.72</td>
</tr>
<tr>
<td>Gonads</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Bladder, Oesophagus, Liver, Thyroid</td>
<td>0.04</td>
<td>0.16</td>
</tr>
<tr>
<td>Bone surface, Brain, Salivary glands, Skin</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1.00</strong></td>
</tr>
</tbody>
</table>

* Remainder tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (*♂*), Small intestine, Spleen, Thymus, Uterus/cervix (*♀*).

$$E = \sum_T w_T \left( \frac{H^M_T + H^E_T}{2} \right)$$
Proposed C2 Publications

• 2008
  – Radionuclide Decay Data (ICRP 107)
  – Reference Phantoms of Male/Female (ICRP 108)
• 2009
  – Dose Conversion Coefficients for External Radiation Sources (ICRP 74, revised)
  – Radiation Exposure of Aircrew (ICRU/ICRP)
• 2010
  – Radiation Protection Dosimetry in Space
  – Internal SAF Values for Reference Male/Female
  – Computational Phantoms for Infant and Child
• 2011
  – Occupational Intakes of Radionuclides, Part 1
  – Computational Phantoms for Pregnant Female, Embryo, and Fetus
  – Internal SAF Values for Embryo, Fetus, Children, and Pregnant Female
• 2012
  – Public Exposures to Radionuclides
• 2013
  – Radionuclides in Wounds
• 2014
  – Occupational Intakes of Radionuclides, Part 2 & 3
  – Doses to Embryo, Fetus and Nursing Infant
ICRP Anatomical Model - Phantoms

• Medical image data provides
  – Improved anatomical realism
  – Studies indicate dosimetric impact (photons)
    • Few tens percent external
    • Order magnitude on internal sources

• ICRP desires to adopt computational phantoms
  – Limitations of voxel models
    • Individual organ topology
    • Individual organ masses

• ICRP Reference computational phantoms
  – Needs to represent population average
  – Reference Man Publications 23 and 89
Reference Adult Phantoms

Mathematical

Voxel Male & Female
Calculation of Effective Dose

\[ E = \sum_{T} w_T \left[ \frac{H^M_T + H^F_T}{2} \right] \]
Ongoing Task Efforts

• Nuclear Decay Data – w JAEA
  – Data for 1252 radionuclides

• DCAL Software Update
  – ACTACAL Module
    • Human Alimentary Tract Model (ICRP 100)
    • Changes in Respiratory Tract Model
  – SEECAL Module
    • New Phantom, SAF Data
  – EPACAL Module
    • Effective Dose Formulation
  – Utilities
    • Retention/Excretion for bioassay

• Biokinetic Models
  – Iodine, transurancis, etc.

• Computations of Dose Coefficients
Structure of Biokinetic Models

• Identify major pools within systemic tissue
• Identify physiological processes
  – Behavior in skeleton connected to bone restructuring
• Identify routes of excretion
• Realistic directions of movement
• Include sufficient number of compartments to address different phases of retention
Compartment Modeling
Time after uptake to blood (d)

Urinary excretion (%/d)

Recent injection data

Mayak workers

1940 Injection data

ICRP Pub. 67

Proposed model
The graph illustrates the concentration of Pu in blood (%), plotted against time after injection (d). It compares three datasets:

- Modern injection data: represented by blue dots.
- ICRP Pub. 67: represented by red dashed line.
- Proposed model: represented by black line.

The x-axis represents time after injection (d) on a log scale ranging from $10^{-3}$ to $10^{3}$, while the y-axis represents Pu in blood (%) on a log scale ranging from $10^{-2}$ to $10^{2}$. The data points and lines highlight the trend and distribution of Pu levels over time.
Regulatory Game Plan

• 2011 ICRP dose coefficients for workers
• 2012 ICRP dose coefficient for public
• Game Plan for US Federal agencies
  – Await ICRP
  – Proceed by
    • Adopting ICRP 103 weighting factors
    • Adopting ICRP 107 nuclear decay data
    • Use ORNL mathematical phantom series (UF-ORNL)
    • Update FGR 11 – FGR 13