Radiation Protection Recommendations
ICRP Publication 103

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Society of Nuclear Medicine
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International Commission on Radiological Protection: ICRP

- Established by the International Congresses of Radiology in 1928
  - Formed as International X-Ray and Radium Protection Committee to address protection in medical radiology
  - Post WW II (1950) expanded to all aspects of radiation protection and given present name
  - International Commission on Radiation Measurements and Units (ICRU), formed in 1928, is a sister commission

- Issues recommendations on the principles of radiation protection
  - Form the basis for more detailed regulations and guidance issued by national authorities
  - Recommendations and advice of ICRP are published on a regular basis, and made available as the Annals of the ICRP
  - Recommendation and advice published in Annals of the ICRP (Elsevier Science)

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Structure of the ICRP

• Main Commission (12 members and a chairman)
  – Committee 1. Radiation Effects
  – Committee 2. Doses from Radiation Exposures
  – Committee 3. Protection in Medicine
  – Committee 4. Application of ICRP Recommendations
  – Committee 5. Protection of the Environment

• Membership
  – Committee members (15 – 20) appointed by Main Commission
  – Members serve as individuals, not representatives of their country
  – Committee work carried out in Task Groups and Working Parties

• Commission is a registered charity in UK
ICRP Recommendations

• Radiation Protection Recommendations
  – Objective: provide appropriate standard of protection without unduly limiting beneficial practices that giving rise to radiation exposure
    – 1959 ICRP Publication 1
    – 1977 ICRP Publication 26
    – 1991 ICRP Publication 60
    – 2007 ICRP Publication 103

• US regulations based on Publication 26 or earlier
Radiation Protection Guidance

• Scope of Guidance
  – Prospective Applications
    • Provide scientific basis for regulatory system
    • Stochastic health effects prime driver
    • Establish good-practice guidelines (planning)
  – Retrospective Applications
    • Evaluation of actual exposures
    • Unplanned exposures or radionuclide intakes
    • Stochastic and deterministic health effects of concern
  – Exposure categories
    • Occupational Exposure
    • Public exposure
    • Medical exposure (dose limits not applicable to patients)
Biological Considerations

• Adverse Health effects
  – Deterministic effects: Effect occurs at doses in excess of a threshold
  – Stochastic effects: cancer and heritable effects; probability of occurrence a function of dose
    • LNT assumption (linear no threshold model)

• Nominal risk coefficients

<table>
<thead>
<tr>
<th>Exposed population</th>
<th>Cancer</th>
<th>Heritable effects</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present(^1)</td>
<td>Publ. 60</td>
<td>Present(^1)</td>
</tr>
<tr>
<td>Whole</td>
<td>5.5</td>
<td>6.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Adult</td>
<td>4.1</td>
<td>4.8</td>
<td>0.1</td>
</tr>
</tbody>
</table>

\(^1\) Values from Annex A.

Table 1. Detriment-adjusted nominal risk coefficients (10\(^{-2}\) Sv\(^{-1}\)) for stochastic effects after exposure to radiation at low dose rate.

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ICRP 103 Dose Limits

• Three principles of radiation protection:
  – justification, limitation, optimization

• Recommended annual dose limits:
  – Effective dose: 20 mSv (2 rem) over 5-years, no year in excess of 50 mSv (5 rem)
  – Tissue equivalent dose
    • Lens of eye: 150 mSv (15 rem)
    • Skin and hands/feet: 500 mSv (50 rem)
  – Declared pregnant woman (fetus): 1 mSv (0.1 rem)

Dose limits unchanged from ICRP 60
Evolution not Revolution

In the 2007 ICRP 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.

However the US has not updated its regulations beyond the 1975 ICRP recommendations of ICRP Publication 26.
Dosimetric Quantities

- **Absorbed Dose** \((D)\). Physical quantity imparted energy per unit mass \((1 \text{ Gy} = 1 \text{ J/kg})\).

- **Equivalent Dose** \((H_T)\). Protection quantity, product of the absorbed dose \((D_{R,T})\) due to radiation \(R\) in tissue \(T\) and radiation weighting factor \((w_R)\). That is, \(H_T = \sum D_{R,T} w_R\).

- **Effective Dose** \((E)\). Protection quantity, sum of the products of equivalent dose \((H_T)\) and tissue weighting factor \((w_T)\). That is, \(E = \sum H_T w_T\).
Radiation Weighting Factor

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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 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, a continuous function of neutron energy</td>
<td>(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).

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

$$H_T = \sum_R w_R D_{T,R}$$

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### Tissue Weighting Factors, $w_T$

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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>1.00</td>
<td></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 (♀).

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Dosimetric Quantities

- ICRP Protection Quantities
  - Effective dose
  - Equivalent dose in tissues
  - Non measurable quantities

- ICRU Operational Quantities
  - Measurable quantities of external radiation fields that adequately represent the protection quantities
    - Personal dose equivalent $Hp(10)$
    - Ambient dose equivalent $H*(10)$
Calculation of Effective Dose

Radionuclide Intake &
External Exposure

Male phantom
Absorbed doses, $D^M_T$

Equivalent
doses, $H^M_T$

Sex-averaged
equivalent doses, $H_T$

Female phantom
Absorbed doses, $D^F_T$

Equivalent
doses, $H^F_T$

Effective dose, $E$

$$E = \sum T w_T \left[ \frac{H^M_T + H^F_T}{2} \right]$$

Male

Female

Reference Male

Reference Female

Reference Person

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Committee 2 Ongoing Tasks

- Update dosimetric models and data
  - Publication 107 updates nuclear decay data
  - Publication 108 (in press) on Reference Male/Female Phantoms
  - Specific absorbed fractions calculations
  - Respiratory tract model updated (Publication 66 updates)
  - Revision of Publication 74 on external radiation
  - Update/expansion of information on systemic biokinetics

- Task Groups
  - Task Group on Dose Calculations (DOCAL)
  - Task Group on Internal Dosimetry (INDOS)

- Working Parties
  - Alpha epidemiology (w C1)
  - Publication 74, revised (joint w ICRU)
  - Space Radiation (ICRP report)
  - Use of Effective Dose (C2, C3, C4)
Possible Issues In US Adoption

• Change in occupational annual dose limit
  – Impact of change from 50 to 20 mSv

• Gender considerations
  – Is female worker adequately protected?

• ICRP’s schedule of supportive documents
  – 2011 Occupational Intakes of Radionuclides, Part 1
  – 2012 Public Exposures to Radionuclides
  – 2014 Occupational Intakes of Radionuclides, Part 2/3

• Need coordinated action of Federal agencies

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