RI-10 RADIONUCLIDE DATA

PURPOSE
This procedure provides a ready reference to radiation protection data for commonly used radionuclides. The quick reference guide provides equations for calculating doses. Use of these equations and examples are covered in Module-5 training. Data for nuclides not listed herein may be obtained from the RCO.

RULES AND REGULATIONS
Radionuclide data used for radiation protection calculations shall be obtained from regulatory authorities or reputable scientific advisory organizations.

DEFINITIONS
Reference Quantity (RQ): A quantity of a radionuclide (expressed in microcuries) related to its relative hazard potential and used to prescribe requirements for handling, monitoring, labeling and disposal.

Annual Limit on Intake (ALI): The quantity of a radionuclide (expressed in millicuries) which, if taken into the body, produces an effective dose equivalent in risk to the annual whole body dose limit of 5 rem or the annual dose limit to an individual organ of 50 rem, whichever is lower. Because of differences in physiological transport mechanisms, the ALIs vary depending on the route of intake. For purposes of contamination control and bioassay procedures, the ALI for ingestion is used, since that is the most common route of accidental intake in research laboratories.

Sewer Release Limits: The maximum concentration (expressed in μCi/mL) that can be released via the sanitary sewer. Sewer release is limited to radionuclides with half-lives \( \leq 16 \) days and at a concentration at or below the sewer release limit before pouring is initiated.

Gamma Ray Constants (mrem\( \cdot \)m\(^2\)/hr\( \cdot \)mCi):
Penetrating - the dose rate from photons at 1 meter from a point source of 1 millicurie, assumed to be proportional to the inverse of the square of the distance between the point source and the receptor.

Skin Dose Constant CF (rem\( \cdot \)cm\(^2\)/μCi/hr) - dose rate to the basal epidermal cells from contamination on the skin, expressed in microcuries per unit area of skin (μCi/cm\(^2\)) over an area of at least 1 cm\(^2\).
**Action Level:** A level of contamination in which immediate action is required. The appropriate action depends on the type of radiation emitted, the radionuclide ALI, the location of contamination and the level of contamination compared to the action level.
Useful Equations

1. Radioactive decay, where $A$ is current activity from starting activity of $A_0$ and $t_{1/2}$ is the half life:
   \[
   A = A_0 e^{-\lambda t} \quad \text{where} \quad \lambda = \frac{\ln(2)}{t_{1/2}}
   \]

2. External absorbed dose rate from a point $\beta$ source of activity ($A$) at a distance ($d$):
   \[
   \dot{D} = \left(27 \frac{\text{rad} \cdot \text{m}^2}{\text{Ci} \cdot \text{h}}\right) \cdot \frac{A}{d^2}
   \]

3. Skin absorbed dose rate from an area $\beta$ source on the skin surface, where $A$ is the activity, $\alpha$ is the area covered, and $C_f$ is the dose rate conversion factor from the Varskin Chart, above:
   \[
   \dot{D} = C_f \cdot \frac{A}{\alpha}
   \]

4. External exposure rate ($\dot{X}$) from a point $\gamma$ source of activity ($A$) at a distance ($d$). $\Gamma$ is the exposure rate constant.
   \[
   \dot{X} = \Gamma \cdot \frac{A}{d^2}
   \]

5. Internal dose equivalents for effective ($E$) whole body or a target ($T$) organ:
   \[
   H_{E,50} = \frac{A}{ALI} (5 \cdot \text{rem}) \quad \text{or} \quad H_{T,50} = \frac{A}{ALI} (50 \cdot \text{rem})
   \]

6. Dose Equivalent (H) (rem) from Absorbed Dose ($D_A$) (rad) and a Quality Factor (Q) (rem/rad):
   \[
   H = D_A \cdot Q
   \]
## RADIONUCLIDE CATEGORIES AND DATA

(For data on radionuclides not listed below, contact the RCO.)

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Half-life</th>
<th>Reference Quantity (μCi)</th>
<th>Ingestion ALI (mCi)</th>
<th>Gamma Ray Constant (mrem*m²)</th>
<th>Skewer Release Limits (μCi/mL)</th>
<th>Sewer Release Limits (mrem/cm²)</th>
<th>Skin Dose Rate Constant (μCi/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“LOW-BETAS” - low-energy beta or electron emitters with negligible external exposure potential and ALI’s &gt; 1 millicurie.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^3$H</td>
<td>12 yrs</td>
<td>1000</td>
<td>3.5$^*$</td>
<td>0</td>
<td>1E-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{14}$C</td>
<td>5730 yrs</td>
<td>100</td>
<td>0.875$^*$</td>
<td>0</td>
<td>3E-5</td>
<td>1.10</td>
<td></td>
</tr>
<tr>
<td>$^{33}$P</td>
<td>25.4 days</td>
<td>100</td>
<td>6</td>
<td>0</td>
<td>8E-5</td>
<td>2.99</td>
<td></td>
</tr>
<tr>
<td>$^{35}$S</td>
<td>87 days</td>
<td>100</td>
<td>6</td>
<td>0</td>
<td>1E-4</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>$^{36}$Cl</td>
<td>3x10$^7$ yrs</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>2E-5</td>
<td>7.20</td>
<td></td>
</tr>
<tr>
<td>$^{45}$Ca</td>
<td>165 days</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>2E-5</td>
<td>3.03</td>
<td></td>
</tr>
<tr>
<td>$^{55}$Fe</td>
<td>2.7 yrs</td>
<td>100</td>
<td>9</td>
<td>0</td>
<td>1E-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{63}$Ni</td>
<td>100 yrs</td>
<td>10</td>
<td>9</td>
<td>0</td>
<td>1E-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{99}$Tc</td>
<td>2x10$^7$ yrs</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>6E-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{147}$Pm</td>
<td>2.6 yrs</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>7E-7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| $^{32}$P | 14.3 days | 10 | 0.03$^*$ | 0 | 9E-6 | 6.03 | |
| $^{86}$Rb | 18.7 days | 100 | 0.5 | 0.05 | 7E-6 | | |
| $^{90}$Sr | 28.6 yrs | 0.1 | 0.03 | 0 | 5E-7 | 5.46 | |

| “IODINES” - radioiodines are treated as a separate category for exposure evaluation. Emphasis is on prevention of intake by ingestion or inhalation. |
| $^{125}$I | 60 days | 1 | 0.04$^*$ | 0.07 | 2E-6 | | |
| $^{129}$I | 6x10$^9$ yrs | 0.1 | 0.005 | 0.13 | 2E-7 | | |
| $^{131}$I | 8 days | 1 | 0.008$^*$ | 0.22 | 1E-6 | 6.30 | |

| “GASES” - noble gases present minimal exposure potential or waste disposal problems. |
| $^{85}$Kr | 10.7 yrs | 100 | N/A | 0 | N/A | | |
| $^{133}$Xe | 5.2 days | 100 | N/A | 0.1 | N/A | | |

<p>| “ALPHAS” – includes naturally occurring as well as man-made radionuclides. Emphasis is on prevention of intake by ingestion or inhalation. |
| $^{232}$Th (nat) | 14x10$^9$ yrs | 100 | 0.0007 | 0 | 3E-8 | | |
| $^{235}$U (nat) | 4.5x10$^9$ yrs | 100 | 0.01 | 0 | 3E-8 | | |
| $^{239}$Pu | 2.1x10$^6$ yrs | 100 | 6x10$^{-6}$ | 0 | 2E-8 | | |
| $^{241}$Pu | 14.4 yrs | 100 | 0.0003 | 0 | 1E-6 | | |
| $^{241}$Am | 458 yrs | 100 | 0.01 | 0.15 | 2E-14 | | |</p>
<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Half-life</th>
<th>Reference Quantity (μCi)</th>
<th>Ingestion ALI (mCi)</th>
<th>Gamma Ray Constant (mrem* m^2)</th>
<th>Sewer Release Limits (μCi/mL)</th>
<th>Skin Dose Rate Constant At 0.07 mm (mrem* cm^2) (μCi/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24Na</td>
<td>0.625 days</td>
<td>10</td>
<td>4</td>
<td>1.89</td>
<td>5E-5</td>
<td>1.10</td>
</tr>
<tr>
<td>51Cr</td>
<td>28 days</td>
<td>1000</td>
<td>40</td>
<td>0.12</td>
<td>5E-5</td>
<td>0.29</td>
</tr>
<tr>
<td>54Mn</td>
<td>312 days</td>
<td>10</td>
<td>2</td>
<td>0.51</td>
<td>3E-5</td>
<td>6E-5</td>
</tr>
<tr>
<td>57Co</td>
<td>271 days</td>
<td>100</td>
<td>4</td>
<td>0.15</td>
<td>6E-5</td>
<td>0.29</td>
</tr>
<tr>
<td>67Ga</td>
<td>3.3 days</td>
<td>100</td>
<td>7</td>
<td>0.11</td>
<td>1E-4</td>
<td>1.10</td>
</tr>
<tr>
<td>68Ga</td>
<td>68 min</td>
<td>100</td>
<td>20</td>
<td>0.54</td>
<td>2E-4</td>
<td>2E-4</td>
</tr>
<tr>
<td>68Ge</td>
<td>288 days</td>
<td>100</td>
<td>5</td>
<td>0.06</td>
<td>6E-5</td>
<td>0.06</td>
</tr>
<tr>
<td>82Sr</td>
<td>64.8 days</td>
<td>10</td>
<td>3</td>
<td>0.75</td>
<td>4E-5</td>
<td>0.06</td>
</tr>
<tr>
<td>95Nb</td>
<td>35 days</td>
<td>10</td>
<td>2</td>
<td>0.48</td>
<td>3E-5</td>
<td>0.97</td>
</tr>
<tr>
<td>99Mo</td>
<td>2.8 days</td>
<td>100</td>
<td>1</td>
<td>0.11</td>
<td>2E-5</td>
<td>1E-3</td>
</tr>
<tr>
<td>99mTc</td>
<td>0.25 days</td>
<td>100</td>
<td>80</td>
<td>0.12</td>
<td>1E-3</td>
<td>0.89</td>
</tr>
<tr>
<td>103Ru</td>
<td>39 days</td>
<td>10</td>
<td>2</td>
<td>0.33</td>
<td>3E-5</td>
<td>2.40</td>
</tr>
<tr>
<td>109Cd</td>
<td>2.6 yrs</td>
<td>10</td>
<td>0.4</td>
<td>1.33</td>
<td>6E-6</td>
<td>5E-6</td>
</tr>
<tr>
<td>111In</td>
<td>2.8 days</td>
<td>100</td>
<td>4</td>
<td>0.5</td>
<td>6E-5</td>
<td>1.40</td>
</tr>
<tr>
<td>113Sn</td>
<td>115 days</td>
<td>10</td>
<td>2</td>
<td>0.18</td>
<td>3E-5</td>
<td>1E-4</td>
</tr>
<tr>
<td>121I</td>
<td>0.542 days</td>
<td>100</td>
<td>3</td>
<td>0.28</td>
<td>1E-4</td>
<td>6E-5</td>
</tr>
<tr>
<td>152Gd</td>
<td>242 days</td>
<td>10</td>
<td>5</td>
<td>0.17</td>
<td>6E-5</td>
<td>0.46</td>
</tr>
<tr>
<td>195Au</td>
<td>183 days</td>
<td>10</td>
<td>5</td>
<td>0.09</td>
<td>7E-5</td>
<td>0.97</td>
</tr>
<tr>
<td>198Hg</td>
<td>1.7 days</td>
<td>10</td>
<td>2</td>
<td>0.1</td>
<td>3E-5</td>
<td>2.40</td>
</tr>
<tr>
<td>199Au</td>
<td>2.7 days</td>
<td>100</td>
<td>3</td>
<td>0.07</td>
<td>8E-5</td>
<td>2E-5</td>
</tr>
<tr>
<td>201Tl</td>
<td>3 days</td>
<td>100</td>
<td>20</td>
<td>0.09</td>
<td>2E-4</td>
<td>9E-5</td>
</tr>
<tr>
<td>203Pb</td>
<td>2.2 days</td>
<td>10</td>
<td>5</td>
<td>0.68</td>
<td>7E-5</td>
<td>7E-5</td>
</tr>
</tbody>
</table>

**ALL OTHER NUCLIDES** - not included in one of the above groups are assumed to have significant potentials for both external and internal exposures and must be evaluated individually.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Half-life</th>
<th>Reference Quantity (μCi)</th>
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<th>Gamma Ray Constant (mrem* m^2)</th>
<th>Sewer Release Limits (μCi/mL)</th>
<th>Skin Dose Rate Constant At 0.07 mm (mrem* cm^2) (μCi/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22Na</td>
<td>2.6 yrs</td>
<td>10</td>
<td>0.4</td>
<td>1.33</td>
<td>6E-6</td>
<td>7.20</td>
</tr>
<tr>
<td>46Sc</td>
<td>84 days</td>
<td>10</td>
<td>0.9</td>
<td>1.17</td>
<td>1E-5</td>
<td>5.10</td>
</tr>
<tr>
<td>59Fe</td>
<td>44.6 days</td>
<td>10</td>
<td>0.8</td>
<td>0.66</td>
<td>1E-5</td>
<td>4.60</td>
</tr>
<tr>
<td>60Co</td>
<td>5.27 yrs</td>
<td>1</td>
<td>0.2</td>
<td>1.37</td>
<td>3E-6</td>
<td>3E-6</td>
</tr>
<tr>
<td>65Zn</td>
<td>244 days</td>
<td>10</td>
<td>0.4</td>
<td>0.33</td>
<td>5E-6</td>
<td>5E-6</td>
</tr>
<tr>
<td>75Se</td>
<td>118 days</td>
<td>10</td>
<td>0.5</td>
<td>0.86</td>
<td>7E-6</td>
<td>0.36</td>
</tr>
<tr>
<td>106Ru</td>
<td>367 days</td>
<td>1</td>
<td>0.2</td>
<td>0</td>
<td>3E-6</td>
<td>3E-6</td>
</tr>
<tr>
<td>109Cd</td>
<td>453 days</td>
<td>10</td>
<td>0.3</td>
<td>0.18</td>
<td>6E-6</td>
<td>6E-6</td>
</tr>
<tr>
<td>137Cs</td>
<td>30.0 yrs</td>
<td>10</td>
<td>0.1</td>
<td>0.34</td>
<td>1E-5</td>
<td>1E-5</td>
</tr>
<tr>
<td>192Ir</td>
<td>74 days</td>
<td>10</td>
<td>0.9</td>
<td>0.59</td>
<td>1E-5</td>
<td>1E-5</td>
</tr>
<tr>
<td>203Hg</td>
<td>47 days</td>
<td>10</td>
<td>0.5</td>
<td>0.25</td>
<td>7E-6</td>
<td>7E-6</td>
</tr>
</tbody>
</table>

* The ALI is not applicable to microspheres, which are highly insoluble particles, typically greater than 0.01 mm diameter. They require external exposure control and monitoring, but are not readily absorbed from the gastrointestinal tract. If inhaled, because of their size, they are most likely to be deposited in the upper respiratory tract, from which they would be cleared by the mucous transport and swallowed.

7 These ALI’s reflect the radiation hazards associated with using various types of DNA-labeled compounds. The lowest values are listed to follow the ALARA principle; ALIs varied for different compounds. These values were taken from recommendations in NCRP Report #63 (Tritium and other Radionuclide Labeled Organic Compounds Incorporated in Genetic Material).
## CONTAMINATION LIMITS AND ACTION LEVELS\(^1\)

### NUCLIDE CATEGORY

- **Electron and/or photon emitters:**
  - with ingestion ALI ≥ 1 mCi: \(1 \text{nCi (2,000 dpm; 40 Bq)} \text{ per 100 cm}^2\)
  - with ingestion ALI < 1 mCi: \(0.1 \text{nCi (200 dpm; 4 Bq)} \text{ per 100 cm}^2\)
- **Alpha-particle emitters:** \(0.01 \text{nCi (20 dpm; 0.4 Bq)} \text{ per 100 cm}^2\)

### LOCATION

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>QUANTITY</th>
<th>REQUIRED ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin or hair</td>
<td>Any</td>
<td>Immediate removal by gentle washing</td>
</tr>
<tr>
<td></td>
<td>&gt;1 AL</td>
<td>Immediate removal and bioassay(^3) within normal interval</td>
</tr>
<tr>
<td></td>
<td>&gt;10 AL</td>
<td>Immediate removal and bioassay(^3) within 5 days</td>
</tr>
<tr>
<td>Clothing, personal or</td>
<td>&gt;1 AL</td>
<td>Do not remove clothing from the lab; wash in the lab or store for decay</td>
</tr>
<tr>
<td>Skin contact likely</td>
<td>&gt;10 AL</td>
<td>Bioassay(^3) within five (5) days</td>
</tr>
<tr>
<td>Skin contact unlikely</td>
<td>&gt;10 AL</td>
<td>Bioassay(^3) within normal interval</td>
</tr>
<tr>
<td>Surfaces or objects that are readily accessible or normally touched, e.g. bench tops, handles, etc.</td>
<td>&gt;1 AL</td>
<td>Until decontaminated, isolate, cover, label, etc. to prevent personnel contact; indicate location and activity in survey record</td>
</tr>
<tr>
<td></td>
<td>&gt;10 AL</td>
<td>Decontaminate immediately; bioassay(^3) required within normal interval for potentially exposed individuals</td>
</tr>
<tr>
<td></td>
<td>&gt;100 AL</td>
<td>Decontaminate immediately; bioassay(^3) required within 5 days for potentially exposed individuals</td>
</tr>
<tr>
<td>Equipment or facilities to be released for unrestricted use</td>
<td>&gt;0.5 AL</td>
<td>Do not release until criteria are satisfied</td>
</tr>
<tr>
<td></td>
<td>&gt;5 AL</td>
<td>Do not release until criteria are satisfied</td>
</tr>
<tr>
<td>Other surfaces or objects (not readily accessible or normally touched)</td>
<td>&gt;1 AL</td>
<td>Label the contaminated area or object; indicate location and activity on survey record</td>
</tr>
<tr>
<td></td>
<td>&gt;10 AL</td>
<td>Decontaminate within one week</td>
</tr>
</tbody>
</table>

\(^1\)Based on NRC Reg. Guide 8.23, Radiation Safety Surveys at Medical Institutions, Rev. 1, Jan. 1981.

\(^2\)All contamination is presumed to be removable until proven otherwise. The limits are expressed as activity per 100 square centimeters, rounded to one significant figure. For all surfaces except skin, the contamination may be averaged over no more than 300 cm\(^2\) for determining the appropriate action.

\(^3\)All requirements for bioassays in this table are for screening bioassays.