# The Health Physics and Radiological Health Handbook

**Revised Edition**

Edited
by
Bernard Shleien, Pharm. D.
Certified Health Physicist, ABHP FAPHA

Scinta, inc.
Silver Spring, MD

**Published by**
**Scinta, Inc. 2421 Homestead Drive , Silver Spring Md. 20902**

Manufactured in the United States

ISBN 0-917251-05-9
Library of Congress Catalog Card Number 92-60543

**Table 6.1 Specific Gamma Ray Dose Constants for Selected Nuclides Important to Radiological Assessment and Protection**
(After Unger and Trubey ORNL/RSIC-45 1981)

The unshielded gamma ray dose–equivalent rate at 1 meter from a point source, i.e., the specific gamma ray dose constant, is a useful quantity in radiation protection applications. An extensive compilation of the nuclear data required to compute this constant is available (Kocher 1981) for approximately 500 nuclides important to dosimetry and radiological assessment applications, and it has been used to compute a table of the specific gamma ray dose constant. In addition, the half–life, mean attenuation coefficient, and thickness for 95% attenuation with a lead shield have been computed.

The data were computed on a different basis from earlier tabulations (Nachtigall 1969). The dose equivalent rate is given in SI units as mSv/h for a unit source of 1 MBq. To convert to the previous common normalization, one may note that 1 mCi is equal to 37 MBq and 1 Sv is equal to 100 rem. That is, to convert data in units of (mSv/h)/MBq to (mrem/h)/$\mu$Ci, multiply by 3.7.

A second difference is that the conversion of gamma ray flux density was taken to be:

$$\ln D(E) = A + B(\ln E) + C(\ln E)^2 + F(\ln E)^3 \qquad \text{(rem/h)(cm}^2\text{–s)} \qquad (1)$$

where the energy is in units of MeV, and the constants are given in Table 6.1.1 taken from ANSI 1977.

The specific gamma ray dose constant, $\Gamma$, was summed over n according to:

$$\Gamma = (1/4\pi R^2)\ \Sigma\ S_i\ D(E_i) \qquad \text{(rem/h per Bq)} \qquad (2)$$

where R = 100 cm,
n = number of gamma rays emitted by the nuclide,
$S_i$ = emission probability of each gamma ray,
$E_i$ = energy of the gamma ray (Mev),
$D(E_i)$ = dose rate per unit flux density from Eq. 1.

Only gamma rays of energy greater than 0.01 MeV were included.

The mean attenuation coefficient[a] was determined by first computing the thickness of lead required for 95% attenuation, i.e.,

$$0.05\ \Gamma = \Sigma\ \Gamma_i\ \exp(-\mu(E_i)\ t) \qquad (3)$$

where $\Gamma_i = S_i\ D(E_i)/(4\pi R^2)$
$\mu E_i$ = linear attenuation coefficient (Hubbell 1969) for lead,
t = thickness required (cm).

The value of t was determined by an iterative procedure, i.e., Newton's method. The value of the mean attenuation coefficient was determined by solving the following equation for $\mu$:

$$0.05 = \exp(-\mu t).$$

[a] An alternative description of $\mu$ as employed in Table 6.1.2 might be the effective attenuation coefficient for lead at 95% attenuation.

The results, presented in Table 6.1.2 were computed using computer-readable data (Kocher 1981) available as DLC-80/DRALIST from the Radiation Shielding Information Center. The computations were performed using a computer program, SPEC-GAM, programmed by the first author for the ORNL Engineering Physics Information Centers (EPIC) Data General Eclipse S/130 computer in FORTRAN.

**Table 6.1.1 Gamma Ray Flux-to-Dose Rate Conversion Factors**
**Polynomial Coefficients in Analytic Form**
**$\ln D(E) = A + Bx + Cx^2 + Fx^3$**
**$D(E)$ = (rem/h)(cm$^2$-s), $E$ = Photon Energy in MeV and $x = \ln E$**
(After Unger and Trubey ORNL/RSIC-45 1981)

| Photon Energy (Mev) | | A | B | C | F |
|---|---|---|---|---|---|
| 0.01 to | 0.03 | -20.477 | -1.7454 | | |
| 0.03 to | 0.5 | -13.626 | -0.57117 | -1.0954 | -0.24897 |
| 0.5 to | 5.0 | -13.133 | 0.72008 | -0.033603 | |
| 5.0 to | 15.0 | -12.791 | 0.28309 | 0.10873 | |

**Table 6.1.2 Specific Gamma Ray Dose Constants at 1 Meter**
**Units: Γ in (mSv/h)/MBq, $\mu$ in $cm^{-1}$**
(After Unger and Trubey ORNL/RSIC-45 1981)

| Nuclide | Half-Life | Γ | $\mu$ | Nuclide | Half-Life | Γ | $\mu$ |
|---|---|---|---|---|---|---|---|
| 7Be | 53.4d | 9.292-6 | 1.879 | 59Fe | 44.6d | 1.789-4 | 0.705 |
| 11C | 20.5m | 1.937-4 | 1.695 | 56Co | 78.8d | 5.205-4 | 0.643 |
| 13N | 10.0m | 1.938-4 | 1.695 | 57Co | 270.9d | 4.087-5 | 39.800 |
| 16N | 7.1s | 3.984-4 | 0.495 | 58Co | 70.8d | 1.659-4 | 1.008 |
| 15O | 2.0m | 1.940-4 | 1.695 | 58mCo | 9.1h | 2.637-8 | 528.9 |
| 18F | 1.8h | 1.879-4 | 1.695 | 60Co | 5.3y | 3.703-4 | 0.679 |
| 22Na | 2.6y | 3.620-4 | 0.854 | 60mCo | 10.5m | 9.057-7 | 0.837 |
| 24Na | 15.0h | 5.237-4 | 0.525 | 61Co | 1.6h | 2.286-5 | 1.706 |
| 27Mg | 9.5m | 1.449-4 | 0.869 | 56Ni | 6.1d | 2.941-4 | 1.002 |
| 28Mg | 20.9h | 2.375-4 | 0.763 | 57Ni | 1.5d | 2.911-4 | 0.681 |
| 26Al | 7.2+5y | 4.047-4 | 0.652 | 65Ni | 2.5h | 8.038-5 | 0.655 |
| 28Al | 2.2m | 2.384-4 | 0.548 | 61Cu | 3.4h | 1.536-4 | 1.499 |
| 31Si | 2.6h | 1.306-7 | 0.676 | 62Cu | 9.7m | 1.910-4 | 1.680 |
| 38Cl | 37.2m | 1.942-4 | 0.527 | 64Cu | 12.7h | 3.566-5 | 1.615 |
| 41Ar | 1.8h | 1.881-4 | 0.667 | 67Cu | 61.9d | 2.363-5 | 13.011 |
| 40K | 1.28+9y | 2.208-5 | 0.619 | 62Zn | 9.3h | 8.990-5 | 1.592 |
| 42K | 12.4h | 3.869-5 | 0.604 | 65Zn | 244.4d | 8.924-5 | 0.738 |
| 43K | 22.6h | 1.811-4 | 1.545 | 69Zn | 55.6m | 1.168-9 | 2.362 |
| 45Ca | 162.7d | 8.072-12 | 823.3 | 69mZn | 13.8h | 7.983-5 | 2.153 |
| 47Ca | 4.5d | 1.581-4 | 0.686 | 66Ga | 9.4h | 3.504-4 | 0.615 |
| 49Ca | 8.7m | 3.615-4 | 0.472 | 67Ga | 3.3d | 3.004-5 | 4.768 |
| 44Sc | 3.9h | 3.602-4 | 0.918 | 68Ga | 1.1h | 1.789-4 | 1.609 |
| 46Sc | 83.8d | 3.155-4 | 0.787 | 72Ga | 14.1h | 3.936-4 | 0.643 |
| 46mSc | 18.7s | 1.809-5 | 24.378 | 68Ge | 288.d | 1.634-5 | 1345. |
| 47Sc | 3.4d | 2.170-5 | 18.513 | 71Ge | 11.8d | 1.653-5 | 1345. |
| 48Sc | 1.8d | 5.117-4 | 0.728 | 77Ge | 11.3h | 1.934-4 | 1.089 |
| 49Sc | 57.4m | 1.407-7 | 0.556 | 72As | 1.1d | 3.148-4 | 1.107 |
| 44Ti | 47.3y | 3.909-5 | 28.726 | 73As | 80.3d | 3.784-5 | 662.1 |
| 45Ti | 3.1h | 1.653-4 | 1.688 | 74As | 17.8d | 1.472-4 | 1.475 |
| 51Ti | 5.8m | 7.130-5 | 2.109 | 76As | 1.1d | 7.408-5 | 1.036 |
| 48V | 16.0d | 4.598-4 | 0.770 | 77As | 1.6d | 1.699-6 | 2.522 |
| 52V | 3.7m | 2.057-4 | 0.626 | 73Se | 7.1h | 2.969-4 | 2.212 |
| 49Cr | 42.1m | 2.029-4 | 1.765 | 75Se | 119.8d | 2.323-4 | 9.079 |
| 51Cr | 27.7d | 6.320-6 | 3.833 | 77Br | 2.4d | 1.923-4 | 3.068 |
| 52Mn | 5.6d | 5.430-4 | 0.773 | 80Br | 17.4m | 2.166-5 | 1.625 |
| 52mMn | 21.4m | 3.903-4 | 0.797 | 80mBr | 4.4h | 1.900-4 | 698.2 |
| 54Mn | 312.7d | 1.382-4 | 0.932 | 82Br | 1.5d | 4.377-4 | 0.906 |
| 56Mn | 2.6h | 2.496-4 | 0.661 | 83Br | 2.4h | 1.401-6 | 1.612 |
| 57Mn | 1.5m | 3.031-5 | 1.692 | 84Br | 31.8m | 2.392-4 | 0.573 |
| 52Fe | 8.3h | 1.413-4 | 1.857 | 85Br | 172. s | 1.059-5 | 0.834 |

**Table 6.1.2 Specific Gamma Ray Dose Constants (Continued)**
**Units: Γ in (mSv/h)/MBq, μ in $cm^{-1}$**
(After Unger and Trubey ORNL/RSIC-45 1981)

| Nuclide | Half-Life | Γ | μ | Nuclide | Half-Life | Γ | μ |
|---|---|---|---|---|---|---|---|
| 79Kr | 1.5d | 1.631-4 | 3.139 | 91Nb | 1.0+4y | 8.832-5 | 1330. |
| 81Kr | 2.1+5y | 1.172-4 | 795.2 | 91mNb | 61. d | 7.160-5 | 3.692 |
| 83mKr | 1.8h | 3.209-5 | 801.4 | 92Nb | 3.6+7y | 3.414-4 | 1.097 |
| 85Kr | 10.7y | 4.232-7 | 1.681 | 92mNb | 10.1d | 2.413-4 | 0.977 |
| 85mKr | 4.5h | 4.328-5 | 9.045 | 93mNb | 14.6y | 1.421-5 | 1292. |
| 87Kr | 1.3h | 1.169-4 | 0.627 | 94Nb | 2.0+4y | 2.648-4 | 0.983 |
| 88Kr | 2.8h | 2.769-4 | 0.556 | 94mNb | 6.3m | 5.481-5 | 1180. |
| 89Kr | 3.2m | 2.626-4 | 0.622 | 95Nb | 35.1d | 1.298-4 | 1.023 |
| 90Kr | 32.3s | 2.073-4 | 0.733 | 95mNb | 3.6d | 6.390-5 | 16.959 |
| 81Rb | 4.6h | 2.264-4 | 2.452 | 96Nb | 23.3h | 4.120-4 | 0.926 |
| 82Rb | 1.2m | 2.104-4 | 1.572 | 97Nb | 1.2h | 1.175-4 | 1.203 |
| 83Rb | 86.2d | 2.085-4 | 2.186 | 97mNb | 60. s | 1.262-4 | 1.063 |
| 84Rb | 32.9d | 2.326-4 | 1.176 | 91Mo | 15.5m | 1.898-4 | 1.660 |
| 86Rb | 18.7d | 1.458-5 | 0.747 | 93Mo | 3500. y | 7.963-5 | 1292. |
| 88Rb | 17.8m | 8.701-5 | 0.571 | 99Mo | 2.8d | 3.052-5 | 1.165 |
| 89Rb | 15.4m | 2.960-4 | 0.630 | 101Mo | 14.6m | 2.391-4 | 0.736 |
| 90Rb | 157. s | 2.548-4 | 0.518 | 95Tc | 20.0h | 2.092-4 | 1.179 |
| 90mRb | 258.0s | 4.429-4 | 0.585 | 95mTc | 61. d | 1.939-4 | 1.407 |
| 82Sr | 25.0d | 1.065-4 | 842.8 | 96Tc | 4.3d | 4.899-4 | 0.994 |
| 85Sr | 64.8d | 2.052-4 | 2.244 | 96mTc | 51.5m | 4.430-5 | 2.427 |
| 85mSr | 1.1h | 6.004-5 | 8.972 | 97Tc | 2.6+6y | 7.596-5 | 1176. |
| 87mSr | 2.8h | 8.010-5 | 2.872 | 97mTc | 89. d | 5.233-5 | 1060. |
| 89Sr | 50.6d | 2.205-8 | 0.858 | 98Tc | 4.2+6y | 2.430-4 | 1.130 |
| 91Sr | 9.5h | 1.118-4 | 0.865 | 99Tc | 2.1+5y | 1.242-10 | 21.144 |
| 92Sr | 2.7h | 1.946-4 | 0.651 | 99mTc | 6.0h | 3.317-5 | 27.731 |
| 93Sr | 7.3m | 3.665-4 | 0.780 | 101Tc | 14.2m | 6.916-5 | 2.913 |
| 86Y | 14.7h | 6.292-4 | 0.782 | 97Ru | 2.9d | 1.194-4 | 10.310 |
| 87Y | 3.3d | 1.861-4 | 2.486 | 103Ru | 39.4d | 8.970-5 | 1.724 |
| 88Y | 106.6d | 4.819-4 | 0.661 | 105Ru | 4.4h | 1.397-4 | 1.202 |
| 90mY | 3.2h | 1.316-4 | 2.213 | 103mRh | 56.1m | 6.912-6 | 864.0 |
| 91Y | 58.5d | 5.403-7 | 0.697 | 105Rh | 1.5d | 1.588-5 | 3.949 |
| 91mY | 49.7m | 1.028-4 | 1.527 | 105mRh | 45. s | 4.251-5 | 98.565 |
| 92Y | 3.5h | 3.971-5 | 0.784 | 106Rh | 29.9s | 3.734-5 | 1.260 |
| 93Y | 10.1h | 1.396-5 | 0.696 | 103Pd | 17.0d | 6.219-5 | 871.6 |
| 86Zr | 16.5h | 2.383-4 | 11.219 | 109Pd | 13.5h | 1.310-7 | 1.706 |
| 88Zr | 83.4d | 1.710-4 | 3.559 | 106mAg | 8.5d | 5.237-4 | 0.948 |
| 89Zr | 3.3d | 2.662-4 | 1.046 | 108Ag | 2.4m | 4.399-6 | 1.545 |
| 95Zr | 64.0d | 1.258-4 | 1.059 | 108mAg | 127. y | 3.436-4 | 1.392 |
| 97Zr | 16.9h | 2.922-5 | 0.803 | 109mAg | 39.6s | 2.722-5 | 548.6 |
| 90Nb | 14.6h | 6.597-4 | 0.627 | 110Ag | 24.6s | 5.558-6 | 1.210 |

**Table 6.1.2 Specific Gamma Ray Dose Constants (Continued)**
**Units: Γ in (mSv/h)/MBq, $\mu$ in $cm^{-1}$**
(After Unger and Trubey ORNL/RSIC-45 1981)

| Nuclide | Half-Life | Γ | $\mu$ | Nuclide | Half-Life | Γ | $\mu$ |
|---|---|---|---|---|---|---|---|
| 110mAg | 249.9d | 4.466-4 | 0.876 | 131mTe | 30. h | 2.452-4 | 0.895 |
| 111Ag | 7.5d | 5.329-6 | 3.440 | 132Te | 3.3d | 7.549-5 | 10.115 |
| 109Cd | 464. d | 4.983-5 | 683.6 | 133Te | 12.4m | 1.584-4 | 0.898 |
| 111mCd | 48.7m | 8.463-5 | 8.502 | 133mTe | 55.4m | 3.689-4 | 0.851 |
| 115Cd | 2.2d | 4.068-5 | 1.711 | 134Te | 41.8m | 1.731-4 | 1.365 |
| 115mCd | 44.6d | 3.433-6 | 0.778 | 122I | 3.6m | 1.901-4 | 1.555 |
| 117Cd | 2.5h | 1.740-4 | 0.733 | 123I | 13.1h | 7.478-5 | 19.341 |
| 117mCd | 3.4h | 2.935-4 | 0.619 | 124I | 4.2d | 2.050-4 | 0.968 |
| 111In | 2.8d | 1.356-4 | 10.321 | 125I | 60.1d | 7.432-5 | 373.1 |
| 113mIn | 1.7h | 6.567-5 | 2.858 | 126I | 12.9d | 1.055-4 | 1.452 |
| 114In | 1.2m | 6.223-6 | 1.358 | 128I | 25.0m | 1.616-5 | 1.988 |
| 114mIn | 49.5d | 4.074-5 | 2.318 | 129I | 1.6+7y | 3.401-5 | 287.0 |
| 115mIn | 4.4h | 5.329-5 | 4.220 | 130I | 12.4h | 3.791-4 | 1.187 |
| 116mIn | 54.1m | 3.660-4 | 0.674 | 131I | 8.0d | 7.647-5 | 2.409 |
| 117In | 43.8m | 1.359-4 | 1.682 | 132I | 2.3h | 3.858-4 | 0.972 |
| 117mIn | 1.9h | 3.060-5 | 5.608 | 133I | 20.8h | 1.105-4 | 1.321 |
| 113Sn | 115.1d | 4.844-5 | 462.8 | 134I | 52.6m | 4.251-4 | 0.845 |
| 117mSn | 13.6d | 6.796-5 | 26.595 | 135I | 6.6h | 2.327-4 | 0.664 |
| 119mSn | 293.0d | 2.789-5 | 517.0 | 136I | 83. s | 3.417-4 | 0.579 |
| 123Sn | 129.2d | 1.062-6 | 0.744 | 122Xe | 20.1h | 4.867-5 | 7.257 |
| 125Sn | 9.6d | 4.674-5 | 0.735 | 123Xe | 2.1h | 1.416-4 | 1.147 |
| 126Sn | 1.0+5y | 3.408-5 | 31.647 | 125Xe | 16.8h | 9.622-5 | 4.757 |
| 117Sb | 2.8h | 8.219-5 | 14.115 | 127Xe | 36.4d | 9.331-5 | 7.526 |
| 122Sb | 2.7d | 8.223-5 | 1.400 | 129mXe | 8.9d | 6.165-5 | 235.8 |
| 124Sb | 60.2d | 2.883-4 | 0.714 | 131mXe | 11.8d | 2.533-5 | 263.7 |
| 125Sb | 2.8y | 1.028-4 | 1.764 | 133Xe | 5.2d | 2.783-5 | 39.877 |
| 126Sb | 12.4d | 4.860-4 | 1.172 | 133mXe | 2.2d | 3.034-5 | 19.750 |
| 126mSb | 19.0m | 2.824-4 | 1.266 | 135Xe | 9.1h | 5.121-5 | 5.015 |
| 127Sb | 3.9d | 1.200-4 | 1.255 | 135mXe | 15.4m | 8.651-5 | 1.668 |
| 129Sb | 4.4h | 2.315-4 | 0.840 | 137Xe | 3.8m | 3.346-5 | 1.247 |
| 121Te | 16.8d | 1.455-4 | 1.683 | 138Xe | 14.1m | 1.679-4 | 0.611 |
| 121mTe | 154. d | 6.703-5 | 5.779 | 126Cs | 1.6m | 2.166-4 | 1.581 |
| 123Te | 1.0+13y | 2.687-5 | 429.8 | 129Cs | 1.3d | 9.725-5 | 3.213 |
| 123mTe | 119.7d | 5.261-5 | 24.041 | 131Cs | 9.7d | 3.363-5 | 310.3 |
| 125mTe | 58. d | 6.168-5 | 368.9 | 132Cs | 6.5d | 1.556-4 | 1.295 |
| 127Te | 9.4h | 9.428-7 | 2.419 | 134Cs | 2.1y | 2.701-4 | 1.095 |
| 127mTe | 109. d | 1.977-5 | 373.5 | 134mCs | 2.9h | 1.904-5 | 75.989 |
| 129Te | 1.2h | 1.833-5 | 2.063 | 136Cs | 13.2d | 3.632-4 | 0.872 |
| 129mTe | 33.6d | 1.997-5 | 2.000 | 137Cs | 30.17y | $1.032 \times 10^4$ | |
| 131Te | 25.0m | 8.073-5 | 1.203 | 138Cs | 32.2m | 3.422-4 | 0.634 |

**Table 6.1.2 Specific Gamma Ray Dose Constants (Continued)**
**Units: Γ in (mSv/h)/MBq, μ in $cm^{-1}$**
(After Unger and Trubey ORNL/RSIC-45 1981)

| Nuclide | Half-Life | Γ | μ | Nuclide | Half-Life | Γ | μ |
|---|---|---|---|---|---|---|---|
| 139Cs | 9.4m | 4.260-5 | 0.596 | 162Gd | 9.7m | 8.341-5 | 2.282 |
| 131Ba | 11.8d | 1.244-4 | 2.239 | 157Tb | 150. y | 2.426-6 | 114.4 |
| 133Ba | 10.5y | 1.231-4 | 4.188 | 160Tb | 72.3d | 1.788-4 | 0.834 |
| 133mBa | 1.6d | 3.372-5 | 8.792 | 162Tb | 7.8m | 1.924-4 | 1.018 |
| 135mBa | 1.2d | 2.974-5 | 9.494 | 157Dy | 8.1h | 8.357-5 | 4.052 |
| 137mBa | 2.6m | 1.081-4 | 1.224 | 165Dy | 2.3h | 6.193-6 | 1.817 |
| 139Ba | 1.4h | 7.717-6 | 2.807 | 166Dy | 3.4d | 1.550-5 | 23.196 |
| 140Ba | 12.8d | 4.446-5 | 1.889 | 166Ho | 1.1d | 6.270-6 | 0.879 |
| 141Ba | 18.3m | 1.562-4 | 0.981 | 166mHo | 1200.0y | 2.870-4 | 1.140 |
| 142Ba | 10.7m | 1.537-4 | 0.841 | 169Er | 9.4d | 3.406-10 | 46.160 |
| 141La | 3.9h | 6.112-6 | 0.633 | 171Er | 7.5h | 8.010-5 | 3.957 |
| 142La | 1.6h | 3.656-4 | 0.558 | 170Tm | 128.6d | 1.673-6 | 29.074 |
| 139Ce | 137.7d | 5.554-5 | 22.320 | 171Tm | 1.9y | 2.597-7 | 60.086 |
| 141Ce | 32.5d | 1.979-5 | 26.056 | 169Yb | 32.0d | 8.837-5 | 13.301 |
| 143Ce | 1.4d | 6.893-5 | 2.109 | 175Yb | 4.2d | 8.233-6 | 2.998 |
| 144Ce | 284.3d | 6.302-6 | 35.806 | 177Lu | 6.7d | 7.636-6 | 10.935 |
| 142Pr | 19.1h | 8.106-6 | 0.591 | 177mLu | 160.1d | 2.112-4 | 3.983 |
| 143Pr | 13.6d | 1.524-12 | 1.061 | 181Hf | 42.4d | 1.061-4 | 2.078 |
| 144Pr | 17.3m | 4.600-6 | 0.619 | 182Ta | 114.7d | 2.086-4 | 0.751 |
| 144mPr | 7.2m | 9.933-6 | 184.2 | 181W | 120.9d | 1.389-5 | 52.038 |
| 147Nd | 11.0d | 3.769-5 | 2.234 | 185W | 75.1d | 5.465-9 | 33.602 |
| 149Nd | 1.7h | 8.112-5 | 2.200 | 187W | 23.8h | 8.886-5 | 1.353 |
| 143Pm | 265. d | 7.216-5 | 1.222 | 188W | 69.4d | 3.615-7 | 5.327 |
| 144Pm | 363. d | 2.958-4 | 1.299 | 182Re | 2.7d | 3.078-4 | 0.853 |
| 145Pm | 17.7y | 2.418-5 | 152.1 | 182mRe | 12.7h | 1.994-4 | 0.761 |
| 146Pm | 2020. d | 1.462-4 | 1.316 | 183Re | 70. d | 4.257-5 | 17.021 |
| 147Pm | 2.6d | 7.232-10 | 36.526 | 184Re | 38.0d | 1.573-4 | 0.963 |
| 148Pm | 5.4d | 8.937-5 | 0.741 | 184mRe | 169. d | 7.678-5 | 1.211 |
| 148mPm | 41.3d | 3.567-4 | 1.210 | 186Re | 3.8d | 4.909-6 | 28.571 |
| 149Pm | 2.2d | 2.317-6 | 2.479 | 188Re | 17.0h | 1.094-5 | 1.324 |
| 151Pm | 1.2d | 7.086-5 | 1.966 | 185Os | 93.6d | 1.310-4 | 1.219 |
| 151Sm | 90. y | 2.442-8 | 776.6 | 190mOs | 9.9m | 3.018-4 | 1.684 |
| 153Sm | 1.9d | 2.440-5 | 69.799 | 191Os | 15.4d | 1.837-5 | 34.767 |
| 152Eu | 13.6y | 2.012-4 | 0.831 | 191mOs | 13.0h | 1.449-6 | 40.828 |
| 152mEu | 9.3h | 5.746-5 | 0.911 | 193Os | 1.2d | 1.414-5 | 2.450 |
| 154Eu | 8.8y | 2.042-4 | 0.802 | 190Ir | 11.8d | 2.681-4 | 1.580 |
| 155Eu | 5.0y | 1.804-5 | 28.563 | 190mIr | 1.2h | 6.120-11 | 456.9 |
| 156Eu | 15.2d | 1.992-4 | 0.647 | 190mIr | 3.2h | 1.499-5 | 40.962 |
| 153Gd | 241.6d | 4.659-5 | 79.273 | 192Ir | 74.0d | 1.599-4 | 2.331 |
| 159Gd | 18.6h | 1.059-5 | 3.622 | 193mIr | 11.9d | 1.017-7 | 37.618 |

**Table 6.1.2 Specific Gamma Ray Dose Constants (Continued)**
**Units: Γ in (mSv/h)/MBq, μ in $cm^{-1}$**
(After Unger and Trubey ORNL/RSIC-45 1981)

| Nuclide | Half-Life | Γ | μ | Nuclide | Half-Life | Γ | μ |
|---|---|---|---|---|---|---|---|
| 194Ir | 19.1h | 1.673-5 | 1.248 | 211Po | 0.5s | 1.328-6 | 1.016 |
| 194mIr | 171. d | 4.372-4 | 1.587 | 213Po | 4.2-6s | 5.146-9 | 1.002 |
| 191Pt | 2.7d | 6.588-5 | 2.483 | 214Po | 1.6-4s | 1.398-8 | 0.975 |
| 193mPt | 4.3d | 4.649-6 | 40.629 | 215Po | 1.8-3s | 2.861-8 | 2.152 |
| 195mPt | 4.0d | 2.029-5 | 36.632 | 216Po | 0.1s | 2.424-9 | 0.965 |
| 197Pt | 18.3h | 5.647-6 | 17.673 | 211At | 7.2h | 6.120-5 | 61.088 |
| 197mPt | 1.6h | 1.931-5 | 4.581 | 217At | 0.032s | 4.331-8 | 1.378 |
| 194Au | 1.6d | 1.784-4 | 0.753 | 218Rn | 0.035s | 1.367-7 | 1.337 |
| 195Au | 183. d | 2.362-5 | 36.236 | 219Rn | 4.0s | 1.419-5 | 3.555 |
| 195mAu | 30.6s | 4.132-5 | 6.174 | 220Rn | 55.6s | 9.723-8 | 1.534 |
| 196Au | 6.2d | 9.922-5 | 3.261 | 222Rn | 3.8d | 7.390-8 | 1.690 |
| 198Au | 2.7d | 7.882-5 | 2.317 | 221Fr | 4.8m | 1.193-5 | 11.522 |
| 199Au | 3.1d | 1.866-5 | 16.121 | 223Fr | 21.8m | 8.930-5 | 67.566 |
| 197Hg | 2.7d | 1.874-5 | 29.898 | 222Ra | 38.0s | 2.115-6 | 3.912 |
| 197mHg | 23.8h | 2.059-5 | 14.537 | 223Ra | 11.4d | 8.789-5 | 10.794 |
| 203Hg | 46.6d | 6.841-5 | 6.007 | 224Ra | 3.6d | 2.967-6 | 8.124 |
| 200Tl | 1.1d | 2.253-4 | 0.886 | 225Ra | 14.8d | 4.164-5 | 304.4 |
| 201Tl | 3.0d | 2.372-5 | 26.211 | 226Ra | 1600.0y | 3.274-6 | 18.693 |
| 202Tl | 12.2d | 9.438-5 | 2.272 | 225Ac | 10.0d | 5.172-5 | 472.6 |
| 204Tl | 3.8y | 3.014-7 | 30.056 | 227Ac | 21.8y | 2.364-6 | 690.1 |
| 207Tl | 4.8m | 3.524-7 | 0.870 | 228Ac | 6.1h | 2.281-4 | 0.985 |
| 208Tl | 3.1m | 4.605-4 | 0.554 | 226Th | 30.9m | 1.818-5 | 138.9 |
| 209Tl | 2.2m | 3.496-4 | 0.705 | 227Th | 18.7d | 1.145-4 | 14.730 |
| 210Tl | 1.3m | 4.601-4 | 0.736 | 228Th | 1.9y | 2.142-5 | 731.9 |
| 203Pb | 2.2d | 1.828-4 | 8.722 | 229Th | 7340.0y | 1.989-4 | 103.7 |
| 204mPb | 1.1h | 3.650-4 | 0.946 | 230Th | 7.7+4d | 1.861-5 | 815.2 |
| 205Pb | 1.5+7y | 6.789-5 | 1345. | 231Th | 1.1d | 1.473-4 | 679.1 |
| 210Pb | 22.3y | 6.801-5 | 1098. | 232Th | 1.4+10y | 1.848-5 | 828.7 |
| 211Pb | 36.1m | 9.836-6 | 1.211 | 233Th | 22.3m | 2.587-5 | 3.684 |
| 212Pb | 10.6h | 7.389-5 | 11.112 | 234Th | 24.1d | 2.038-5 | 148.5 |
| 214Pb | 26.8m | 8.742-5 | 4.027 | 230Pa | 17.4d | 2.387-4 | 1.322 |
| 206Bi | 6.2d | 6.820-4 | 0.945 | 231Pa | 3.3+4d | 1.011-4 | 131.7 |
| 207Bi | 33.4y | 3.603-4 | 1.015 | 233Pa | 27.0d | 1.335-4 | 7.024 |
| 208Bi | 3.7+5y | 4.110-4 | 0.532 | 234Pa | 6.7h | 5.356-4 | 1.107 |
| 211Bi | 2.1m | 1.274-5 | 3.617 | 234mPa | 1.2m | 2.776-6 | 0.978 |
| 212Bi | 1.0h | 5.264-5 | 1.042 | 230U | 20.8d | 2.463-5 | 683.5 |
| 213Bi | 45.6m | 3.140-5 | 2.094 | 231U | 4.2d | 2.120-4 | 293.4 |
| 214Bi | 19.9m | 2.268-4 | 0.672 | 232U | 72.0y | 2.403-5 | 716.7 |
| 209Po | 102.0y | 9.811-7 | 1.288 | 233U | 1.59+5y | 7.866-6 | 705.0 |
| 210Po | 138. d | 1.424-9 | 0.967 | 234U | 2.44+5y | 2.097-5 | 720.7 |

**Table 6.1.2 Specific Gamma Ray Dose Constants (Continued)**
***Units:* Γ in (mSv/h)/MBq, μ in $cm^{-1}$**
(After Unger and Trubey ORNL/RSIC-45 1981)

| Nuclide | Half-Life | Γ | μ | Nuclide | Half-Life | Γ | μ |
|---|---|---|---|---|---|---|---|
| 235U | 7.04+8y | 9.159-5 | 22.675 | 246Am | 25.0m | 2.149-5 | 0.899 |
| 236U | 2.34+7y | 1.992-5 | 722.4 | 242Cm | 163.2d | 1.949-5 | 1054. |
| 237U | 6.7d | 1.589-4 | 54.239 | 243Cm | 28.5y | 1.286-4 | 23.268 |
| 238U | 4.47+9y | 1.763-5 | 722.5 | 244Cm | 18.1y | 1.741-5 | 1054. |
| 239U | 23.4m | 3.630-5 | 23.988 | 245Cm | 8500.0y | 1.220-4 | 140.0 |
| 240U | 14.1h | 7.686-5 | 921.3 | 246Cm | 4750.0y | 1.551-5 | 1054. |
| 235Np | 1.1y | 6.979-5 | 840.5 | 247Cm | 1.6+7y | 7.217-5 | 2.675 |
| 236Np | 1.15+5y | 2.833-4 | 161.6 | 248Cm | 3.4+5y | 1.227-5 | 1054. |
| 236mNp | 22.5h | 6.390-5 | 69.674 | 249Cm | 1.1h | 4.007-6 | 1.478 |
| 237Np | 2.1+6y | 1.251-4 | 512.0 | 250Bk | 3.2h | 1.834-4 | 0.862 |
| 238Np | 2.1d | 1.497-4 | 0.965 | 248Cf | 333.5d | 1.229-5 | 1271. |
| 239Np | 2.4d | 1.386-4 | 19.449 | 249Cf | 350.6y | 1.119-4 | 3.459 |
| 240Np | 65. m | 3.826-4 | 1.342 | 250Cf | 13.1y | 1.212-5 | 1269. |
| 240mNp | 7.4m | 1.144-4 | 1.489 | 251Cf | 900.0y | 1.162-4 | 43.960 |
| 236Pu | 2.9y | 2.405-5 | 863.6 | 252Cf | 2.6y | 1.131-5 | 1269. |
| 237Pu | 45.3d | 1.039-4 | 212.7 | 253Cf | 17.8d | 2.080-7 | 1272. |
| 238Pu | 87.8y | 2.135-5 | 864.8 | 254Cf | 60.5d | 1.311-11 | 122.5 |
| 239Pu | 2.41+4y | 8.145-6 | 860.3 | 253Es | 20.5d | 6.921-6 | 1196. |
| 240Pu | 6569. y | 2.030-5 | 864.4 | 254Es | 275.7d | 1.490-4 | 1229. |
| 242Pu | 3.76+5y | 1.684-5 | 864.4 | 254mEs | 1.6d | 1.519-4 | 1.404 |
| 243Pu | 5.0h | 2.509-5 | 35.548 | 255Es | 39.8d | 8.529-7 | 1263. |
| 244Pu | 8.3+7y | 1.462-5 | 865.1 | 254Fm | 3.2h | 1.121-5 | 1375. |
| 245Pu | 10.6h | 1.046-4 | 1.432 | 255Fm | 20.1h | 8.721-5 | 1334. |
| 246Pu | 10.9d | 2.727-5 | 10.771 | | | | |
| 241Am | 432.2y | 8.479-5 | 260.7 | | | | |
| 242Am | 16.0h | 5.476-5 | 720.7 | | | | |
| 242mAm | 152.0y | 4.950-5 | 1132. | | | | |
| 243Am | 7380.0y | 8.456-5 | 71.213 | | | | |
| 244Am | 10.1h | 3.168-4 | 1.420 | | | | |
| 245Am | 2.0h | 2.341-5 | 17.710 | | | | |

# Analysis Flow Diagram