Preliminary Remediation Goals for Radionuclides

<u>Carcinogenic Adjustment Factors</u>:

Residential: (soil ingestion, inhalation, fruit, vegetables)

$$IR_{sr}=\frac{ED_{cr}\times IR_c+ED_{ar}\times IR_a}{ED_r}\quad IR_{ir}=\frac{ED_{cr}\times IRA_c+ED_{ar}\times IRA_a}{ED_r}\quad CR_{fr}=\frac{ED_{cr}\times CR_{fc}+ED_{ar}\times CR_{fa}}{ED_r}\quad CR_{vr}=\frac{ED_{cr}\times CR_{vc}+ED_{ar}\times CR_{va}}{ED_r}$$

Agricultural: (soil ingestions, inhalation, vegetables, fruit, swine, poultry, eggs, milk, beef, fish)

$$IR_{sag}=\frac{ED_{cag}\times IR_c+ED_{aag}\times IR_a}{ED_{ag}}\quad IR_{iag}=\frac{ED_{cag}\times IRA_c+ED_{aag}\times IRA_a}{ED_{ag}}\quad CR_{vag}=\frac{ED_{cag}\times CR_{vc}+ED_{aag}\times CR_{va}}{ED_{ag}}\quad CR_{fag}=\frac{ED_{cag}\times CR_{fc}+ED_{aag}\times CR_{fa}}{ED_{ag}}$$

$$IR_{sw}=\frac{ED_{cag}\times IR_{swc}+ED_{aag}\times IR_{swa}}{ED_{ag}}\quad IR_{po}=\frac{ED_{cag}\times IR_{poc}+ED_{aag}\times IR_{poa}}{ED_{ag}}\quad IR_e=\frac{ED_{cag}\times IR_{ec}+ED_{aag}\times IR_{ea}}{ED_{ag}}\quad IR_m=\frac{ED_{cag}\times IR_{mc}+ED_{aag}\times IR_{ma}}{ED_{ag}}$$

$$IR_b=\frac{ED_{cag}\times IR_{bc}+ED_{aag}\times IR_{ba}}{ED_{ag}}\quad IR_{fishag}=\frac{ED_{cag}\times IR_{fishc}+ED_{aag}\times IR_{fisha}}{ED_{ag}}$$

Residential Soil Equation:

$$C_{(pCi/g)}=\frac{TR\times t_r\times\lambda}{ED_r\times\left(1-e^{-\lambda t_r}\right)\times\left[\begin{array}{l}\left(SF_s\times IR_{sr}\times 10^{-3}\,(g/mg)\times EF_r\right)+\left(SF_i\times IR_{ir}\times\frac{10^3\,(g/kg)}{PEF}\times EF_r\times\left[ET_{ro}+\left(ET_{ri}\times DF_i\right)\right]\right)+\\ \left(SF_e\times\frac{EF_r}{365(d/yr)}\times ACF\times\left[ET_o+\left(ET_i\times GSF\right)\right]\right)+\left(SF_f\times\left(CR_{fr}+CR_{wr}\right)\times 10^3\,(g/kg)\times TF_p\times CPF_r\right)\end{array}\right]}$$

Agricultural Soil Equation:

$$C_{(pCi/g)}=\frac{TR\times t_{ag}\times\lambda}{ED_{ag}\left(1-e^{-\lambda t_{ag}}\right)\times\left[ING+INH+EXT+PROD+FISH+BEEF+MILK+EGG+POULTRY+SWINE\right]}$$

Where:

$$ING_{(g/pCi\text{-}yr)}=SF_s\times IR_{sag}\times 10^{-3}\,(g/mg)\times EF_{ag}$$

$$INH_{(g/pCi\text{-}yr)}=SF_i\times IR_{iag}\times\frac{10^3\,(g/kg)}{PEF}\times EF_{ag}\times\left[ET_{ago}+\left(ET_{agi}\times DF_i\right)\right]$$

$$EXT_{(g/pCi\text{-}yr)}=SF_e\times\frac{EF_{ag}}{365(d/yr)}\times ACF\times\left[ET_o+\left(ET_i\times GSF\right)\right]$$

$$PROD_{(g/pCi\text{-}yr)}=\left(CR_{fag}+CR_{mag}\right)\times TF_p\times CPF_{ag}\times 10^3\,(g/kg)\times SF_f$$

$$FISH_{(g/pCi\text{-}yr)} = IR_{fish/ag} \times 10^3\,(g/kg) \times SF_f \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times TF_f \times \frac{A_s}{A_w}$$

$$BEEF_{(g/pCi\text{-}yr)} = IR_b \times \left(\left(TF_b \times FI_b \times TF_p\right) + \left(TF_b \times FI_{sb}\right) + \left(TF_b \times FI_{wb} \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times \frac{1}{DF_w} \right) \right) \times 10^3\,(g/kg) \times SF_f$$

$$MILK_{(g/pCi\text{-}yr)} = IR_m \times \left(\left(TF_m \times FI_m \times TF_p\right) + \left(TF_m \times FI_{sm}\right) + \left(TF_m \times FI_{wm} \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times \frac{1}{DF_w} \right) \right) \times 10^3\,(g/kg) \times SF_f$$

$$EGG_{(g/pCi\text{-}yr)} = IR_e \times \left(\left(TF_e \times FI_{po} \times TF_p\right) + \left(TF_e \times FI_{pos}\right) \right) \times 10^3\,(g/kg) \times SF_f$$

$$POULTRY_{(g/pCi\text{-}yr)} = IR_{po} \times \left(\left(TF_{po} \times FI_{po} \times TF_p\right) + \left(TF_{po} \times FI_{pos}\right) \right) \times 10^3\,(g/kg) \times SF_f$$

$$SWINE_{(g/pCi\text{-}yr)} = IR_{sw} \times \left(\left(TF_{sw} \times FI_{sw} \times TF_p\right) + \left(TF_{sw} \times FI_{ssw}\right) + \left(TF_{sw} \times FI_{wsw} \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times \frac{1}{DF_w} \right) \right) \times 10^3\,(g/kg) \times SF_f$$

Outdoor Worker Equation:

$$C_{(pCi/g)} = \frac{TR \times t_w \times \lambda}{EF_{ow} \times ED_{ow} \times \left(1 - e^{-\lambda t_w}\right) \times \left[\begin{array}{l} \left(SF_s \times IR_{sow} \times 10^{-3}\,(g/mg)\right) + \left(SF_i \times IR_{ow} \times \frac{10^3\,(g/kg)}{PEF} \times \left[ET_{owo} + \left(ET_{owi} \times DF_i\right)\right]\right) + \\ \left(SF_e \times \frac{1}{365\,(d/yr)} \times ACF \times \left[ET_{owo} + \left(ET_{owi} \times GSF\right)\right]\right) \end{array}\right]}$$

Indoor Worker Equation:

$$C_{(pCi/g)} = \frac{TR \times t_w \times \lambda}{EF_{iw} \times ED_{iw} \times \left(1 - e^{-\lambda t_w}\right) \times \left[\begin{array}{l} \left(SF_s \times IR_{siw} \times 10^{-3}\,(g/mg)\right) + \left(SF_i \times IR_{iw} \times \frac{10^3\,(g/kg)}{PEF} \times \left[ET_{iwo} + \left(ET_{iwi} \times DF_i\right)\right]\right) + \\ \left(SF_e \times \frac{1}{365\,(d/yr)} \times ACF \times \left[ET_{iwo} + \left(ET_{iwi} \times GSF\right)\right]\right) \end{array}\right]}$$

Tap Water Equation:

$$C_{(pCi/L)} = \frac{TR}{EF_t \times ED_t \times \left[\left(SF_w \times IR_w\right) + \left(SF_i \times IR_{tap} \times K\right)\right]}$$

Fish Ingestion Equation:

$$C_{(pCi/g)} = \frac{TR}{SF_f \times IR_{ff} \times EF_f \times ED_r}$$

Soil to Groundwater Equations:

Partitioning:

$$SSL_{DC}=C_w\times 10^{-3}\times\left(K_d+\frac{\theta_w}{\rho_b}\right)\times\frac{t\times\lambda}{\left(1-e^{-\lambda t}\right)}$$

Mass Loading:

$$SSL_{DC}=\frac{C_w\times I\times ED_{gw}\times 10^{-3}\times t\times\lambda}{\rho_b\times d_s\times\left(1-e^{-\lambda t}\right)}$$

$$DAF=1+\left(\frac{K\times i\times d}{I\times L}\right)$$

$$d=\left(0.0112\times L^2\right)^{0.5}+d_a\times\left\{1-e^{\left[(-L\times I)/(K\times i\times d_a)\right]}\right\}$$

Supporting Equation:

$$PEF=Q/C\times\frac{3{,}600}{0.036\times(1-V)\times\left(U_m/U_t\right)^3\times F(\chi)}$$

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Preliminary Remediation Goals for Radionuclides

SELECTION:
Your **Analytes/CAS numbers** are:
Cs-137+D
Your **PRGs** are
Residential Soil
Your **Units** are
pCi
Default Parameters
Each PRG you have selected is given below along with the applicable Equations and its associated Default Parameters. For each equation, the default values will be used unless you enter a different value.

Particulate Emission Factor

(needed for Residential Soil, Agricultural Soil, Outdoor Worker Soil, and/or Indoor Worker Soil)

$$PEF = Q/C \times \frac{3{,}600}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$$

Minneapolis (V) City (Climatic Zone)

0.5 Surface (acres)

93.77 Q/C (inverse of the mean conc. at the center of a 0.5-acre-square source) g/m^2-s per k g/m^3

0.5 V (fraction of vegetative cover) unitless

4.69 U_m (mean annual windspeed) m/s

11.32 U_t (equivalent threshold value of windspeed at 7m) m/s

0.194	F(x) (function dependent on U_m/U_t) unitless

NOTES:

1. PEF (particulate emission factor) m^3/kg. Default is 1.36×10^9
2. The Surface Area and City/Climate Zone are used to look up a Q/C. Q/C is the inverse of mean concentration at center of a 0.5 acre-square source (g/m^2-s per kg/m^3). Pick the city with the most similar climatic conditions (map).
3. The F(x) function is derived using Cowherd et al. (1985)

Residential Soil

Radionuclide Contaminants in Soil

$$C_{(pCi/g)} = \frac{TR \times t_r \times \lambda}{ED_r \times \left(1 - e^{-\lambda t_r}\right) \times \left[\begin{array}{l} \left(SF_s \times IR_{sr} \times 10^3\,(g/mg) \times EF_r\right) + \left(SF_i \times IR_{ir} \times \frac{10^3\,(g/kg)}{PEF} \times EF_r \times \left[ET_{ro} + (ET_{ri} \times DF_i)\right]\right) + \\ \left(SF_e \times \frac{EF_r}{365\,(d/yr)} \times ACF \times \left[ET_o + (ET_i \times GSF)\right]\right) + \left(SF_f \times (CR_{fr} + CR_{wr}) \times 10^3\,(g/kg) \times TF_p \times CPF_r\right) \end{array} \right]}$$

Where:

$$IR_{sr} = \frac{ED_{cr} \times IR_c + ED_{ar} \times IR_a}{ED_r}$$

$$IR_{ir} = \frac{ED_{cr} \times IRA_c + ED_{ar} \times IRA_a}{ED_r}$$

$$CR_{vr} = \frac{ED_{cr} \times CR_{vc} + ED_{ar} \times CR_{va}}{ED_r}$$

$$CR_{fr} = \frac{ED_{cr} \times CR_{fc} + ED_{ar} \times CR_{fa}}{ED_r}$$

1.0E-5 TR (target risk) unitless	30 t_r (time of exposure) yr
30 ED_r (exposure duration, ED_{cr} + ED_{ar}) yr	350 EF_r (exposure frequency) d/yr
0.073 ET_{ro} (exposure time fraction, outdoor) unitless	0.683 ET_{ri} (exposure time fraction, indoor) unitless
0.4 DF_i (indoor dilution factor) unitless	0.9 ACF (area correction factor) unitless
0.4 GSF (gamma shielding factor) unitless	0.25 CPF_r (contaminated plant fraction) unitless
6 ED_{cr} (exposure duration, child) yr	24 ED_{ar} (exposure duration, adult) yr
200 IR_c (soil intake rate, child) mg/day	100 IR_a (soil intake rate, adult) mg/day
10 IRA_c (inhalation rate, child) m^3/day	20 IRA_a (inhalation rate, adult) m^3/day
5.4 CR_{fc} (fruit consumption rate, child) kg/yr	20.5 CR_{fa} (fruit consumption rate, adult) kg/yr
3.8 CR_{vc} (vegetable consumption rate, child) kg/yr	10.4 CR_{va} (vegetable consumption rate, adult) kg/yr

NOTES:

1. SF_s=soil ingestion slope factor (Risk/pCi). radionuclide-specific
2. SF_i=inhalation slope factor (Risk/pCi). radionuclide-specific
3. SF_e=external exposure slope factor (Risk/yr per pCi/g). radionuclide-specific
4. SF_p=food ingestion slope factor (Risk/pCi). radionuclide-specific
5. IR_s=age-adjusted ingestion rate (mg/day).
6. IR_i=age-adjusted inhalation rate (m^3/day).

7. CR_f=age-adjusted fruit consumption rate (kg/yr).
8. CR_v=age-adjusted vegetable consumption rate (kg/yr).
9. PEF=particulate emission factor (m^3/kg).
10. TF_p=soil-to-plant transfer factor. radionuclide-specific
11. λ= Decay constant (0.693/halflife) yr^{-1}. Radionuclide-specific.
12. The curie (Ci), the customary unit of activity, is equal to 3.7 x 10^{10} nuclear transformations per second. 1 picocurie (pCi) = 10^{-12} Ci. The International System (SI) unit of activity is the becquerel (1 Bq =1 nuclear transformation per second).

Preliminary Remediation Goals for Radionuclides

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Sr-90+D
Your **PRGs** are
Residential Soil
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pCi
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Residential Soil

Radionuclide Contaminants in Soil

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Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Toxicity: Soil Ingestion Slope Factor-Adult (risk/pCi)	Toxicity: Water Ingestion Slope Factor (risk/pCi)	Toxicity: Food Ingestion Slope Factor (risk/pCi)	Toxicity: Inhalation Slope Factor (risk/pCi)	Toxicity: External Exposure Slope Factor (risk/y per pCi/g)	Preliminary Remediation Goals (PRG): Residential Soil (pCi/g)	Preliminary Remediation Goals (PRG): Agricultural Soil (pCi/g)	Preliminary Remediation Goals (PRG): Outdoor Worker Soil (pCi/g)	Preliminary Remediation Goals (PRG): Indoor Worker Soil (pCi/g)	Preliminary Remediation Goals (PRG): Tap Water (pCi/L)	Preliminary Remediation Goals (PRG): Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	Soil to Groundwater: DAF=1 (pCi/g)
Cesium (55)	Cs-137+D	4.33E-11	3.17E-11	3.04E-11	3.74E-11	1.19E-11	2.55E-06	5.97E-02	1.20E-03	1.13E-01	2.53E-01	1.57E+00	4.72E-02	5.66E+01	2.83E+00
Cesium (55)	Cs-138	3.40E-13	1.27E-13	1.58E-13	2.16E-13	4.00E-14	1.19E-05	3.18E+03	3.03E+03	5.19E+03	1.17E+04	3.01E+02	8.17E+00	7.08E+12	3.54E+11
Chlorine (17)	Cl-36	7.66E-12	2.29E-12	3.30E-12	4.44E-12	2.50E-11	1.74E-09	5.65E-02	1.02E-02	1.08E+02	2.35E+02	1.44E+01	3.97E-01		
Chlorine (17)	Cl-38	4.22E-13	1.55E-13	1.93E-13	2.64E-13	9.40E-14	7.93E-06	4.07E+03	3.89E+03	6.74E+03	1.52E+04	2.47E+02	6.68E+00		
Chlorine (17)	Cl-39	3.31E-13	1.21E-13	1.52E-13	2.08E-13	9.36E-14	7.09E-06	3.05E+03	2.93E+03	5.05E+03	1.14E+04	3.13E+02	8.48E+00		
Chromium (24)	Cr-48	1.84E-12	4.07E-13	7.44E-13	1.05E-12	7.51E-13	1.62E-06	5.45E+02	5.45E+02	8.90E+02	2.00E+03	6.40E+01	1.68E+00		
Chromium (24)	Cr-49	3.20E-13	9.10E-14	1.35E-13	1.89E-13	7.36E-14	4.43E-06	6.54E+03	6.54E+03	1.07E+04	2.40E+04	3.53E+02	9.33E+00		
Chromium (24)	Cr-51	4.96E-13	8.88E-14	1.85E-13	2.66E-13	1.67E-13	1.27E-07	2.41E+02	2.41E+02	3.93E+02	8.84E+02	2.57E+02	6.63E+00		
Cobalt (27)	Co-55	1.23E-11	2.38E-12	4.63E-12	6.70E-12	2.07E-12	9.21E-06	1.26E+02	7.59E+00	2.06E+02	4.63E+02	1.03E+01	2.63E-01	6.68E+06	3.34E+05
Cobalt (27)	Co-56	2.56E-11	5.29E-12	1.01E-11	1.43E-11	1.85E-11	1.80E-05	5.96E-01	3.31E-02	9.74E-01	2.19E+00	4.71E+00	1.23E-01	2.62E+02	1.31E+01
Cobalt (27)	Co-57	2.78E-12	4.85E-13	1.04E-12	1.49E-12	2.09E-12	3.55E-07	8.73E+00	9.66E-02	1.44E+01	3.23E+01	4.58E+01	1.18E+00	1.68E+02	8.40E+00
Cobalt (27)	Co-58	7.44E-12	1.57E-12	2.95E-12	4.18E-12	5.99E-12	4.48E-06	2.66E+00	1.27E-01	4.36E+00	9.80E+00	1.61E+01	4.22E-01	1.11E+03	5.56E+01
Cobalt (27)	Co-58m	3.47E-13	5.99E-14	1.26E-13	1.83E-13	6.88E-14	1.00E-12	5.92E+06	5.65E+02	4.33E+08	7.99E+08	3.78E+02	9.64E+00	8.98E+08	4.49E+07
Cobalt (27)	Co-60	4.03E-11	7.33E-12	1.57E-11	2.23E-11	3.58E-11	1.24E-05	3.61E-02	9.01E-04	6.02E-02	1.35E-01	3.03E+00	7.91E-02	2.41E+00	1.21E-01
Cobalt (27)	Co-60m	5.88E-15	2.12E-15	2.66E-15	3.66E-15	3.96E-15	1.86E-08	6.24E+06	1.20E+06	1.02E+07	2.29E+07	1.79E+04	4.82E+02	1.16E+14	5.82E+12
Cobalt (27)	Co-61	6.40E-13	1.32E-13	2.43E-13	3.49E-13	1.43E-13	2.48E-07	4.95E+04	1.59E+03	8.10E+04	1.82E+05	1.96E+02	5.05E+00	1.43E+10	7.16E+08
Cobalt (27)	Co-62m	1.79E-13	6.55E-14	8.25E-14	1.13E-13	3.17E-14	1.35E-05	6.50E+03	5.51E+03	1.06E+04	2.39E+04	5.77E+02	1.56E+01	2.14E+12	1.07E+11
Copper (29)	Cu-60	3.00E-13	1.04E-13	1.37E-13	1.89E-13	5.77E-14	1.93E-05	2.72E+03	2.72E+03	4.44E+03	1.00E+04	3.48E+02	9.33E+00		
Copper (29)	Cu-61	1.20E-12	2.39E-13	4.63E-13	6.70E-13	2.41E-13	3.63E-06	1.64E+03	1.64E+03	2.68E+03	6.03E+03	1.03E+02	2.63E+00		
Copper (29)	Cu-62						4.43E-06	2.83E+04	2.83E+04	4.61E+04	1.04E+05				
Copper (29)	Cu-64	1.72E-12	2.93E-13	6.40E-13	9.32E-13	4.33E-13	8.30E-07	1.92E+03	1.89E+03	3.15E+03	7.08E+03	7.44E+01	1.89E+00		
Copper (29)	Cu-66						4.32E-07	5.53E+05	5.53E+05	9.03E+05	2.03E+06				
Copper (29)	Cu-67	5.29E-12	8.88E-13	1.94E-12	2.83E-12	2.35E-12	3.83E-07	8.38E+02	7.67E+02	1.40E+03	3.15E+03	2.45E+01	6.23E-01		
Curium (96)	Cm-238	8.70E-13	1.65E-13	3.28E-13	4.70E-13	1.35E-11	1.90E-07	4.45E+04	4.40E+04	7.27E+04	1.64E+05	1.45E+02	3.75E+00	1.44E+12	7.21E+10
Curium (96)	Cm-240	9.88E-11	1.53E-11	3.49E-11	5.07E-11	9.51E-09	6.19E-11	2.07E+03	1.23E+02	2.42E+04	4.46E+04	1.36E+00	3.48E-02	1.86E+05	9.29E+03
Curium (96)	Cm-241	1.35E-11	2.15E-12	4.85E-12	7.03E-12	1.01E-10	1.94E-06	1.33E+01	1.31E+01	2.17E+01	4.88E+01	9.82E+00	2.51E-01	9.06E+05	4.53E+04
Curium (96)	Cm-242	1.05E-10	1.87E-11	3.85E-11	5.48E-11	1.51E-08	7.73E-11	3.22E+02	1.89E+01	3.20E+03	5.92E+03	1.24E+00	3.22E-02	4.62E+03	2.31E+02
Curium (96)	Cm-243	2.05E-10	7.84E-11	9.47E-11	1.23E-10	2.69E-08	4.19E-07	3.49E-01	1.27E-01	6.79E-01	1.52E+00	5.03E-01	1.43E-02	3.64E+01	1.82E+00
Curium (96)	Cm-244	1.81E-10	6.88E-11	8.36E-11	1.08E-10	2.53E-08	4.85E-11	6.69E+00	3.04E-01	3.79E+01	6.90E+01	5.70E-01	1.63E-02	4.35E+01	2.17E+00
Curium (96)	Cm-245	2.18E-10	9.14E-11	1.04E-10	1.35E-10	2.77E-08	2.38E-07	4.11E-01	9.22E-02	8.76E-01	1.95E+00	4.58E-01	1.31E-02	7.91E-01	3.96E-02
Curium (96)	Cm-246	2.12E-10	9.03E-11	1.02E-10	1.31E-10	2.77E-08	4.57E-11	3.40E+00	1.29E-01	1.88E+01	3.42E+01	4.67E-01	1.35E-02	8.08E-01	4.04E-02
Curium (96)	Cm-247	2.11E-10	8.58E-11	9.95E-11	1.30E-10	2.50E-08	1.31E-06	8.31E-02	4.28E-02	1.65E-01	3.71E-01	4.79E-01	1.36E-02	8.25E-01	4.13E-02
Curium (96)	Cm-248			9.52E-09	1.23E-08	2.54E-06	3.42E-11	3.89E-01	1.43E-03	4.80E+00	1.08E+01	5.00E-03	1.43E-04	2.59E+01	1.29E+00
Curium (96)	Cm-249	2.18E-13	4.92E-14	8.40E-14	1.20E-13	7.25E-14	8.51E-08	2.23E+05	2.22E+05	3.64E+05	8.19E+05	5.67E+02	1.47E+01	2.83E+13	1.42E+12
Dysprosium (66)	Dy-155	1.35E-12	2.68E-13	5.25E-13	7.47E-13	2.45E-13	2.44E-06	8.33E+02	8.33E+02	1.36E+03	3.06E+03	9.07E+01	2.36E+00		
Dysprosium (66)	Dy-157	5.62E-13	1.21E-13	2.26E-13	3.20E-13	8.33E-14	1.32E-06	1.90E+03	1.90E+03	3.10E+03	6.98E+03	2.11E+02	5.51E+00		
Dysprosium (66)	Dy-159	1.47E-12	2.37E-13	5.29E-13	7.70E-13	1.28E-12	3.19E-08	1.83E+02	1.83E+02	3.00E+02	6.76E+02	9.00E+01	2.29E+00		
Dysprosium (66)	Dy-165	1.15E-12	1.95E-13	4.14E-13	6.03E-13	2.10E-13	9.49E-08	9.17E+04	9.17E+04	1.50E+05	3.37E+05	1.15E+02	2.92E+00		
Dysprosium (66)	Dy-166	3.22E-11	4.48E-12	1.11E-11	1.63E-11	8.36E-12	6.02E-08	3.85E+03	3.86E+03	6.69E+03	1.50E+04	4.29E+00	1.08E-01		
Einsteinium (99)	Es-250	1.44E-13	3.55E-14	5.96E-14	8.36E-14	5.07E-13	1.69E-06	5.73E+03	5.73E+03	9.34E+03	2.10E+04	7.99E+02	2.11E+01		
Einsteinium (99)	Es-251	2.89E-12	4.33E-13	1.02E-12	1.49E-12	6.40E-12	2.55E-07	2.41E+03	2.41E+03	3.94E+03	8.86E+03	4.67E+01	1.18E+00		
Einsteinium (99)	Es-253	1.01E-10	1.44E-11	3.49E-11	5.11E-11	8.84E-09	1.25E-09	2.67E+03	2.77E+03	2.12E+04	4.19E+04	1.36E+00	3.45E-02		
Einsteinium (99)	Es-254	1.50E-10	2.82E-11	5.51E-11	7.81E-11	1.85E-08	8.55E-09	1.03E+02	1.06E+02	4.05E+02	8.52E+02	8.64E-01	2.26E-02		
Einsteinium (99)	Es-254m	7.88E-11	1.11E-11	2.73E-11	4.00E-11	1.53E-09	2.10E-06	2.45E+02	2.45E+02	4.02E+02	9.03E+02	1.74E+00	4.41E-02		
Erbium (68)	Er-161	8.10E-13	1.65E-13	3.15E-13	4.51E-13	1.34E-13	4.09E-06	1.53E+03	1.53E+03	2.50E+03	5.63E+03	1.51E+02	3.91E+00		
Erbium (68)	Er-165	2.42E-13	4.18E-14	8.95E-14	1.30E-13	3.13E-14	3.05E-08	6.40E+04	6.40E+04	1.05E+05	2.35E+05	5.32E+02	1.36E+01		
Erbium (68)	Er-169	7.36E-12	1.02E-12	2.53E-12	3.70E-12	3.85E-12	9.10E-11	8.09E+04	8.41E+04	6.86E+05	1.35E+06	1.88E+01	4.77E-01		
Erbium (68)	Er-171	5.74E-12	8.70E-13	2.02E-12	2.96E-12	9.40E-13	1.42E-06	1.90E+03	1.90E+03	3.10E+03	6.99E+03	2.36E+01	5.96E-01		
Erbium (68)	Er-172	1.70E-11	2.55E-12	5.99E-12	8.77E-12	4.74E-12	2.20E-06	1.87E+02	1.87E+02	3.06E+02	6.88E+02	7.95E+00	2.01E-01		
Europium (63)	Eu-145	6.77E-12	1.46E-12	2.73E-12	3.85E-12	1.81E-12	6.95E-06	2.05E+01	2.05E+01	3.35E+01	7.53E+01	1.74E+01	4.58E-01		
Europium (63)	Eu-146	1.12E-11	2.45E-12	4.55E-12	6.40E-12	2.59E-12	1.16E-05	1.58E+01	1.58E+01	2.58E+01	5.81E+01	1.05E+01	2.76E-01		

Radionuclide Toxicity and Preliminary Remediation Goals for Superfund

Element (Atomic Number)	Isotope	Toxicity: Soil Ingestion Slope Factor (risk/pCi)	Toxicity: Soil Ingestion Slope Factor-Adult (risk/pCi)	Toxicity: Water Ingestion Slope Factor (risk/pCi)	Toxicity: Food Ingestion Slope Factor (risk/pCi)	Toxicity: Inhalation Slope Factor (risk/pCi)	Toxicity: External Exposure Slope Factor (risk/y per pCi/g)	Preliminary Remediation Goals (PRG): Residential Soil (pCi/g)	PRG: Agricultural Soil (pCi/g)	PRG: Outdoor Worker Soil (pCi/g)	PRG: Indoor Worker Soil (pCi/g)	PRG: Tap Water (pCi/L)	PRG: Fish Ingestion (pCi/g)	Soil to Groundwater: DAF=20 (pCi/g)	Soil to Groundwater: DAF=1 (pCi/g)
Samarium (62)	Sm-151	1.59E-12	2.35E-13	5.55E-13	8.07E-13	4.88E-12	3.60E-13	4.65E+02	2.42E+02	8.19E+03	1.48E+04	8.58E+01	2.19E+00		
Samarium (62)	Sm-153	1.40E-11	1.97E-12	4.85E-12	7.10E-12	2.95E-12	1.06E-07	4.02E+03	3.97E+03	6.68E+03	1.50E+04	9.82E+00	2.48E-01		
Samarium (62)	Sm-155	1.13E-13	3.74E-14	4.96E-14	6.88E-14	3.15E-14	2.81E-07	1.96E+05	1.96E+05	3.20E+05	7.21E+05	9.60E+02	2.56E+01		
Samarium (62)	Sm-156	4.26E-12	6.29E-13	1.49E-12	2.18E-12	9.69E-13	3.79E-07	5.69E+03	5.69E+03	9.31E+03	2.09E+04	3.20E+01	8.09E-01		
Scandium (21)	Sc-43	2.21E-12	3.96E-13	8.18E-13	1.18E-12	3.81E-13	4.73E-06	1.10E+03	1.10E+03	1.80E+03	4.05E+03	5.82E+01	1.49E+00		
Scandium (21)	Sc-44	4.22E-12	7.51E-13	1.56E-12	2.25E-12	6.44E-13	9.95E-06	5.20E+02	5.20E+02	8.48E+02	1.91E+03	3.05E+01	7.84E-01		
Scandium (21)	Sc-44m	3.89E-11	6.03E-12	1.38E-11	2.01E-11	6.96E-12	1.15E-06	3.00E+02	2.99E+02	4.92E+02	1.11E+03	3.45E+00	8.77E-02		
Scandium (21)	Sc-46	1.62E-11	3.07E-12	6.22E-12	8.88E-12	2.47E-11	9.63E-06	1.05E+00	1.05E+00	1.71E+00	3.85E+00	7.66E+00	1.99E-01		
Scandium (21)	Sc-47	1.00E-11	1.44E-12	3.49E-12	5.11E-12	3.05E-12	3.62E-07	6.95E+02	6.94E+02	1.14E+03	2.56E+03	1.36E+01	3.45E-01		
Scandium (21)	Sc-48	1.93E-11	3.59E-12	7.33E-12	1.05E-11	3.96E-12	1.62E-05	2.87E+01	2.87E+01	4.68E+01	1.05E+02	6.50E+00	1.68E-01		
Scandium (21)	Sc-49	5.25E-13	1.22E-13	2.05E-13	2.92E-13	1.07E-13	1.90E-08	1.11E+06	1.11E+06	1.82E+06	4.10E+06	2.32E+02	6.04E+00		
Selenium (34)	Se-70	6.92E-13	1.95E-13	2.95E-13	4.11E-13	7.36E-14	4.22E-06	7.04E+03	7.00E+03	1.15E+04	2.59E+04	1.61E+02	4.29E+00		
Selenium (34)	Se-73	1.99E-12	4.48E-13	7.96E-13	1.13E-12	1.99E-13	4.52E-06	6.28E+02	6.19E+02	1.03E+03	2.31E+03	5.98E+01	1.56E+00		
Selenium (34)	Se-73m	2.02E-13	5.07E-14	8.29E-14	1.17E-13	2.06E-14	1.06E-06	2.95E+04	2.93E+04	4.81E+04	1.08E+05	5.74E+02	1.51E+01		
Selenium (34)	Se-75	1.67E-11	6.25E-12	8.14E-12	1.08E-11	3.77E-12	1.45E-06	4.78E+00	3.27E+00	7.94E+00	1.79E+01	5.85E+00	1.63E-01		
Selenium (34)	Se-77m						2.85E-07	1.47E+07	1.47E+07	2.39E+07	5.39E+07				
Selenium (34)	Se-79	1.60E-11	5.29E-12	7.29E-12	9.69E-12	3.33E-12	1.10E-11	4.69E+00	1.32E-01	3.30E+02	5.97E+02	6.53E+00	1.82E-01		
Selenium (34)	Se-81	9.58E-14	3.36E-14	4.29E-14	5.92E-14	1.27E-14	4.68E-08	1.40E+06	1.30E+06	2.30E+06	5.17E+06	1.11E+03	2.98E+01		
Selenium (34)	Se-81m	3.24E-13	8.07E-14	1.30E-13	1.85E-13	3.54E-14	3.56E-08	5.90E+05	4.46E+05	9.75E+05	2.19E+06	3.66E+02	9.53E+00		
Selenium (34)	Se-83	2.33E-13	7.33E-14	1.02E-13	1.43E-13	2.72E-14	1.15E-05	4.71E+03	4.71E+03	7.69E+03	1.73E+04	4.67E+02	1.23E+01		
Silicon (14)	Si-31	1.81E-12	2.97E-13	6.48E-13	9.40E-13	3.05E-13	1.11E-08	6.84E+05	6.85E+05	1.14E+06	2.56E+06	7.35E+01	1.88E+00		
Silicon (14)	Si-32	9.81E-12	1.50E-12	3.44E-12	5.00E-12	2.93E-10	2.18E-11	8.14E+01	6.41E+01	1.05E+03	1.95E+03	1.38E+01	3.53E-01		
Silver (47)	Ag-102	1.56E-13	5.74E-14	7.25E-14	9.95E-14	2.56E-14	1.60E-05	5.91E+03	5.88E+03	9.64E+03	2.17E+04	6.57E+02	1.77E+01	2.73E+13	1.37E+12
Silver (47)	Ag-103	2.96E-13	7.22E-14	1.20E-13	1.69E-13	6.07E-14	3.33E-06	5.57E+03	5.39E+03	9.09E+03	2.05E+04	3.97E+02	1.04E+01	6.37E+11	3.18E+10
Silver (47)	Ag-104	3.77E-13	1.10E-13	1.65E-13	2.29E-13	6.25E-14	1.25E-05	1.41E+03	1.39E+03	2.30E+03	5.17E+03	2.89E+02	7.70E+00	4.17E+11	2.09E+10
Silver (47)	Ag-104m	2.81E-13	8.29E-14	1.21E-13	1.68E-13	4.92E-14	5.50E-06	6.62E+03	6.48E+03	1.08E+04	2.43E+04	3.94E+02	1.05E+01	2.43E+12	1.21E+11
Silver (47)	Ag-105	4.40E-12	9.77E-13	1.77E-12	2.49E-12	2.83E-12	2.15E-06	9.56E+00	5.37E+00	1.57E+01	3.53E+01	2.69E+01	7.08E-01	5.35E+04	2.67E+03
Silver (47)	Ag-106	1.34E-13	4.44E-14	5.92E-14	8.21E-14	2.72E-14	3.08E-06	1.65E+04	1.62E+04	2.69E+04	6.06E+04	8.04E+02	2.15E+01	9.67E+12	4.84E+11
Silver (47)	Ag-106m	1.14E-11	2.82E-12	4.81E-12	6.73E-12	3.54E-12	1.31E-05	7.67E+00	5.69E+00	1.25E+01	2.82E+01	9.90E+00	2.62E-01	4.67E+05	2.34E+04
Silver (47)	Ag-108						8.56E-08	6.01E+06	6.01E+06	9.81E+06	2.21E+07				
Silver (47)	Ag-108m	1.92E-11	5.07E-12	8.14E-12	1.12E-11	2.67E-11	7.18E-06	1.68E-02	6.29E-03	3.25E-02	7.32E-02	5.85E+00	1.57E-01	3.99E-01	1.99E-02
Silver (47)	Ag-109m						7.66E-09	2.41E+08	2.41E+08	3.94E+08	8.85E+08				
Silver (47)	Ag-110						1.69E-07	1.76E+07	1.76E+07	2.87E+07	6.46E+07				
Silver (47)	Ag-110m	2.37E-11	5.96E-12	9.88E-12	1.37E-11	2.83E-11	1.30E-05	2.60E-01	1.52E-01	4.25E-01	9.56E-01	4.82E+00	1.29E-01	1.58E+02	7.92E+00
Silver (47)	Ag-111	2.37E-11	3.36E-12	8.21E-12	1.21E-11	6.66E-12	1.09E-07	7.44E+02	1.36E+01	1.69E+03	3.81E+03	5.80E+00	1.46E-01	3.49E+05	1.75E+04
Silver (47)	Ag-112	5.59E-12	9.10E-13	1.99E-12	2.90E-12	7.25E-13	3.23E-06	2.01E+03	1.25E+03	3.29E+03	7.40E+03	2.39E+01	6.08E-01	4.73E+09	2.36E+08
Silver (47)	Ag-115	3.46E-13	8.92E-14	1.40E-13	1.98E-13	6.81E-14	3.44E-06	1.77E+04	1.71E+04	2.89E+04	6.51E+04	3.40E+02	8.91E+00	5.89E+12	2.94E+11
Sodium (11)	Na-22	1.97E-11	7.47E-12	9.62E-12	1.26E-11	3.89E-12	1.03E-05	8.65E-02	8.52E-02	1.42E-01	3.18E-01	4.95E+00	1.40E-01		
Sodium (11)	Na-24	2.64E-12	9.29E-13	1.23E-12	1.65E-12	4.74E-13	2.20E-05	6.16E+01	6.15E+01	1.00E+02	2.26E+02	3.87E+01	1.07E+00		
Strontium (38)	Sr-80	2.83E-12	6.11E-13	1.09E-12	1.55E-12	4.51E-13	5.08E-11	1.13E+06	8.03E+03	1.58E+08	3.09E+08	4.37E+01	1.14E+00	1.25E+10	6.26E+08
Strontium (38)	Sr-81	4.03E-13	1.17E-13	1.71E-13	2.39E-13	8.07E-14	5.97E-06	8.01E+03	7.71E+03	1.31E+04	2.94E+04	2.78E+02	7.38E+00	1.23E+12	6.14E+10
Strontium (38)	Sr-82	8.47E-11	1.57E-11	3.13E-11	4.48E-11	3.69E-11	5.00E-11	1.09E+02	7.71E-01	2.79E+04	5.05E+04	1.52E+00	3.94E-02	3.36E+03	1.68E+02
Strontium (38)	Sr-83	5.85E-12	1.14E-12	2.21E-12	3.17E-12	1.26E-12	3.60E-06	1.73E+02	9.35E+01	2.84E+02	6.40E+02	2.15E+01	5.56E-01	1.63E+07	8.17E+05
Strontium (38)	Sr-85	5.03E-12	1.42E-12	2.26E-12	3.11E-12	2.56E-12	2.20E-06	5.88E+00	2.49E+00	9.69E+00	2.18E+01	2.11E+01	5.67E-01	6.93E+03	3.47E+02
Strontium (38)	Sr-85m	3.74E-14	1.14E-14	1.67E-14	2.31E-14	8.32E-15	8.21E-07	2.14E+04	2.08E+04	3.49E+04	7.85E+04	2.85E+03	7.63E+01	1.69E+12	8.46E+10
Strontium (38)	Sr-87m	2.69E-13	6.03E-14	1.07E-13	1.51E-13	5.62E-14	1.33E-06	5.43E+03	4.89E+03	8.87E+03	2.00E+04	4.45E+02	1.17E+01	4.49E+10	2.24E+09
Strontium (38)	Sr-89	3.47E-11	6.48E-12	1.28E-11	1.84E-11	2.34E-11	7.19E-09	1.24E+02	9.29E-01	3.43E+03	7.52E+03	3.72E+00	9.59E-02	2.02E+03	1.01E+02
Strontium (38)	Sr-90	9.18E-11	5.18E-11	5.59E-11	6.88E-11	1.05E-10	4.82E-10	3.31E-01	1.92E-03	4.23E+01	7.73E+01	8.52E-01	2.56E-02	2.69E-01	1.34E-02
Strontium (38)	Sr-90+D	1.44E-10	5.92E-11	7.40E-11	9.53E-11	1.13E-10	1.96E-08	2.31E-01	1.39E-03	1.08E+01	2.27E+01	6.44E-01	1.85E-02	2.69E-01	1.34E-02
Strontium (38)	Sr-91	8.81E-12	1.57E-12	3.22E-12	4.66E-12	1.70E-12	3.30E-06	6.42E+02	2.72E+02	1.06E+03	2.38E+03	1.48E+01	3.78E-01	1.30E+08	6.52E+06
Strontium (38)	Sr-92	6.18E-12	1.07E-12	2.25E-12	3.26E-12	1.03E-12	6.69E-06	1.12E+03	7.58E+02	1.83E+03	4.11E+03	2.12E+01	5.41E-01	2.29E+09	1.15E+08