

APPENDIX F

TCEQ VERIFICATION CALCULATION

ESTIMATING THE DOSE TO A RESIDENT LIVING AT THE SITE BOUNDARY DURING THE OPERATING PERIOD IN THE PREDOMINATED WIND DIRECTION FROM THE WCS BY-PRODUCT RADIOACTIVE WASTE DISPOSAL SITE

(Pathways include dust suspension, radon gas, and external radiation from deposited dust.)

TCEQ verification calculations for estimating dose to a resident living at the site boundary in the predominant down wind direction from the site.

Airborne dust from open byproduct waste cell

Maywood waste byproduct source term with natural dust suspension from waste cell

Equations:

$$\text{Dose(mrem/yr)} = \text{Air.conc(Ci/m}^3\text{)} \times \text{breathing.rt(m}^3\text{/yr)} \times \text{frac.yr.exposed} \times \text{DCF.inh(mrem/Ci)} \times \text{resuspension factor(m-1)} \times \text{waste.conc(Ci/m}^3\text{)} \times \text{active depth(m)}$$

$$\text{Air.conc} = \text{Waste.source(Ci/s)} \times \text{X/Q(s/m}^3\text{)} \quad (\text{offsite})$$

$$\text{Waste.source(Ci/s)} = \text{Waste.conc(Ci/m}^3\text{)} \times \text{active.depth(m)} \times \text{resusp.rt(1/s)} \times \text{waste.area(m}^2\text{)}$$

$$\text{X/Q (s/m}^3\text{)} = \text{wind.freq} / (2 \times \pi \times \text{wind.spd(m/s)} \times \text{sigma.y(m)} \times \text{sigma.z(m)})$$

Resuspension rate (1/s)= DOE-HDBK-3010-94, Table 4-18, geometric mean of Nevada TS an Eroding field 1E-11, 1E-9, 2E-9, 2E-7, and 1E-6 s-1

Formula Geometric Mean

$$\left(\prod_{i=1}^n a_i \right)^{1/n} = \sqrt[n]{a_1 \cdot a_2 \cdot \dots \cdot a_n}$$

Parameters:

Byproduct waste volume (m3)	894,000	1,169,000	cy
Area of exposed waste (m2)	19,800	Vol. I, Figure 3.7 worst case active waste slope(288ft) x disposal area width(740ft)	
Average wind speed (m/s)	3.1	WCS weather station, avg 6.04 knots	
Active depth for suspnsn. (m)	0.001	particles > 1 mm not suspended.	
Resuspension rate (1/s)	5.25E-09	DOE-HDBK-3010-94, Table 4-18, GM of NTS, Hanford, eroding field	
Inhalation rate (m3/yr)	8,400	RESRAD default	
Distance to site boundary receptor (m):	777	Stortest distance from Northern edge of waste area to the north site boundary.	
Wind frequency annual avg.	0.13	Wind frequency from the predominate wind direction from the South	
Sigma-y	88	for a conservatively stable Pasquill C stability class, Cember 1996, p. 493.	
Sigma-z	55.00	for a conservatively stable Pasquill C stability class, Cember 1996, p. 494	
X/Q (s/m3)	1.38E-06	Pasquill-Gifford ground level, plume centerline. Adj for wind freq in N, NNE, NNW dirs, Bevelacqua 1999, p357.	
Fraction of yr exposed	1.000	8,760 hr/yr	

Maywood Bulk Waste	Waste Conc Ci/m3	Surface Conc Ci/m2	Site Boundary		Site Boundary	
			Air Conc Ci/m3	FGR #11 Sv/Bq	FGR #11 mrem/Ci	Dose mrem/yr
Pa-231		0.00E+00	0.00E+00	3.47E-04	1.28E+12	0.00E+00
Ac-227		0.00E+00	0.00E+00	1.81E-03	6.70E+12	0.00E+00
Ra-226+D	7.89E-04	7.89E-07	1.13E-16	2.32E-06	8.58E+09	8.16E-03
Pb-214	7.89E-04	7.89E-07	1.13E-16	2.11E-09	7.81E+06	7.42E-06
Bi-214	7.89E-04	7.89E-07	1.13E-16	1.78E-09	6.59E+06	6.26E-06
Pb-210	7.89E-04	7.89E-07	1.13E-16	3.67E-06	1.36E+10	1.29E-02
Po-210	7.89E-04	7.89E-07	1.13E-16	2.54E-06	9.40E+09	8.93E-03
Ra-228+D	3.17E-03	3.17E-06	4.55E-16	1.29E-06	4.77E+09	1.82E-02
Ac-228	3.17E-03	3.17E-06	4.55E-16	8.33E-08	3.08E+08	1.18E-03
Th-228	3.17E-03	3.17E-06	4.55E-16	9.23E-05	3.42E+11	1.30E+00
Ra-224	3.17E-03	3.17E-06	4.55E-16	8.53E-07	3.16E+09	1.21E-02
Pb-212	3.17E-03	3.17E-06	4.55E-16	4.56E-08	1.69E+08	6.44E-04
Bi-212	3.17E-03	3.17E-06	4.55E-16	5.83E-09	2.16E+07	8.24E-05
Tl-208	1.14E-03	1.14E-06	1.64E-16	0.00E+00	0.00E+00	0.00E+00
Th-230	5.87E-04	5.87E-07	8.42E-17	8.80E-05	3.26E+11	2.30E-01
Th-232	3.17E-03	3.17E-06	4.55E-16	4.43E-04	1.64E+12	6.26E+00
U-234	5.87E-04	5.87E-07	8.42E-17	3.58E-05	1.32E+11	9.37E-02
U-235+D	2.70E-05	2.70E-08	3.87E-18	3.32E-05	1.23E+11	4.00E-03
Th-231	2.70E-05	2.70E-08	3.87E-18	2.37E-10	8.77E+05	2.85E-08
U-238+D	5.87E-04	5.87E-07	8.42E-17	3.20E-05	1.18E+11	8.37E-02
Th-234	5.87E-04	5.87E-07	8.42E-17	9.47E-09	3.50E+07	2.48E-05
Pa-234m	5.87E-04	5.87E-07	8.42E-17	0.00E+00	0.00E+00	0.00E+00

Projected Dose to Resident at Site Boundary (mrem/yr) **8.04E+00**

A3 Radon gas from byproduct without interim cover

Doses to Resident Site Boundary during operations

Fernald Silo 1 & 2 source term

Reference for radon flux equations - NUREG/CR-3533, April 1984

Equations:

$$\text{Radon.flux(pCi/m}^2\text{-s)} = \text{Radium.conc(pCi/cm}^3\text{)} \times \text{emanation.coef} \times \text{sqrt(m.decay(s-1)} \times \text{diffusion.coef(cm}^2\text{/s)} \text{)} \times 10,000 \text{ cm}^2\text{/m}^2$$

$$\text{Radon.source(pCi/s)} = \text{Radon.flux(pCi/m}^2\text{-s)} \times \text{area(m}^2\text{)}$$

$$\text{Air.conc.wkrk(pCi/m}^3\text{)} = \text{radon.source(pCi/s)} / [\text{sqrt(waste.area(m}^2\text{))} \times \text{wind.speed(m/s)} \times \text{vertical.mixing(m)}] \quad (\text{box model})$$

$$\text{Air.conc.offsite(pCi/m}^3\text{)} = \text{radon.source(pCi/s)} \times \text{X/Q(s/m}^3\text{)} \quad (\text{Gaussian plume})$$

$$\text{Radon.dose(mrem/yr)} = \text{Air.conc(pCi/m}^3\text{)} \times 0.001 \text{ (m}^3\text{/L)} \times \text{frac.yr.exposed} \times \text{dose.fctr(mrem/yr per pCi/L)}$$

Parameters:

Ra-226 activity concentration(pCi/g)	8.47E+04	Maximum bulk waste byproduct source term, Maywood
Area of exposed waste (m2)	6,870	Vol.1, Figure 3.7, Active Waste Slope which has a 288 ft downward face and a 740 ft maximum width
Radon Dose Conv. Factor	46	mrem/yr per pCi/L, outdoor, 10% eq., reference 10 CFR 20
Thickness of waste (m)	21.33	for use in RAECOM model on Wise-Uranium web site.

Average wind speed (m/s)	3.1	WCS weather station, avg 6.04 knots
Distance to receptor (m):	777	Stortest distance from Northern edge of waste area to the site boundary.
Wind frequency annual avg.	0.13	Wind frequency from the predominate wind direction from the South

Calculations:

Sigma-y	88	for a conservatively stable Pasquill C stability class, Cember 1996, p. 493.
Sigma-z	55.00	for a conservatively stable Pasquill C stability class, Cember 1996, p. 494
X/Q (s/m3)	1.38E-06	Pasquill-Gifford ground level, plume centerline. Adj for wind freq in N, NNE, NNW dirs, Bevelacqua 1999, p357.
Fraction of yr exposed	1.000	8,760 hr/yr
Radon flux (pCi/m2-s)	1.65E+02	using RAECOM model from Wise-Uranium web site
Radon source (pCi/s)	1.13E+06	
Air conc. Site Boundary (pCi/m3)	1.57E+00	

Projected Dose to Resident at Site Boundary (mrem/yr) 7.20E-02

A3b Radon gas from byproduct waste with interim cover

Doses to Resident Site Boundary during operations
 Fernald Silo 1 & 2 source term
 Reference for radon flux equations - NUREG/CR-3533, April 1984

Equations:

Radon.flux(pCi/m2-s) = Radium.conc(pCi/cm3) x emanation.coef x sqrt(rn.decay(s-1) x diffusion.coef(cm2/s)) x 10,000 cm2/m2
 Radon.source(pCi/s) = Radon flux(pCi/m2-s) x area(m2)
 Air.conc.wkr(pCi/m3) = radon.source(pCi/s) / [sqrt(waste.area(m2)) x wind.speed(m/s) x vertical.mixing(m)] (box model)
 Air.conc.offsite(pCi/m3) = radon.source(pCi/s) x X/Q(s/m3) (Gaussian plume)
 Radon.dose(mrem/yr) = Air.conc(pCi/m3) x 0.001(m3/L) x frac.yr.exposed x dose.fctr(mrem/yr per pCi/L)

Parameters:

Ra-226 activity concentration(pCi/g)	8.47E+04	Maximum bulk waste byproduct source term, Maywood
Area of exposed waste (m2)	6,870	Vol. I, Figure 3.7 worst case interim covered area(100ft) x disposal area width(740ft)
Radon Dose Conv. Factor	46	mrem/yr per pCi/L, outdoor, 10% eq., reference 10 CFR 20
Thickness of waste (m)	21.33	for use in RAECOM model on Wise-Uranium web site.
Average wind speed (m/s)	3.1	WCS weather station, avg 6.04 knots
Distance to receptor (m):	777	Stortest distance from Northern edge of waste area to the site boundary.
Wind frequency annual avg.	0.31	Wind frequency from the predominate wind direction from the South

Calculations:

Sigma-y	88	for a conservatively stable Pasquill C stability class, Cember 1996, p. 493.
Sigma-z	55.00	for a conservatively stable Pasquill C stability class, Cember 1996, p. 494
X/Q (s/m3)	3.29E-06	Pasquill-Gifford ground level, plume centerline. Adj for wind freq in N, NNE, NNW dirs, Bevelacqua 1999, p357.
Fraction of yr exposed	1.000	8,760 hr/yr
Radon flux (pCi/m2-s)	3.22E+00	using RAECOM model from Wise-Uranium web site
Radon source (pCi/s)	2.21E+04	
Air conc. Site Boundary (pCi/m3)	3.05E-02	

Projected Dose to Resident at Site Boundary (mrem/yr) 1.40E-03

S3 External radiation from offsite soil (contaminated by dust deposition)

Doses to Site Boundary & Nearest Resident during operations
 Maywood waste is the source term, natural wind suspension of dust, like Pathway A1

Equations:

Dose(mrem/yr) = Ground.conc(Ci/m2) x frac.yr.exposed x DCF.surf(mrem/yr per Ci/m2)
 Ground.conc(Ci/m2) = Air.conc(Ci/m3) x deposition.velocity(m/s) x time(s)
 Air.conc = Waste.source(Ci/s) x X/Q(s/m3) (offsite)
 Waste.source(Ci/s) = Waste.conc(Ci/m3) x active.depth(m) x resusp.rt(1/s) x waste.area(m2)
 X/Q (s/m3) = wind.freq / (pi x wind.spd(m/s) x sigma.y(m) x sigma.z(m))

Parameters:

Bulk waste volume (m3)	894,000	1,169,000 cy
Area of exposed waste (m2)	19,800	1/8 of a cell exposed
Average wind speed (m/s)	3.1	WCS weather station, avg 6.04 knots
Active depth for suspnsn. (m)	0.001	particles > 1 mm not suspended
Resuspension rate (1/s)	5.25E-09	DOE-HDBK-3010-94, Table 4-18, GM of NTS, Hanford, eroding field
Dust deposition velocity (m/s)	0.01	EPA, typical
Inhalation rate (m3/yr)	8,400	RESRAD
Deposition time (s)	3.156E+07	1 year
Unit conversion	1.168E+23	converts Sv-m2/Bq-s to mrem-m2/Ci-yr
Distance to receptor (m):	777	Stortest distance from Northern edge of waste area to the site boundary.
Wind frequency annual avg.	0.13	Wind frequency from the predominate wind direction from the South

Calculations:

Sigma-y	88	for a conservatively stable Pasquill C stability class, Cember 1996, p. 493.
---------	----	--

Sigma-z 55.00 for a conservatively stable Pasquill C stability class, Cember 1996, p. 494
 X/Q (s/m3) 1.38E-06 Pasquill-Gifford ground level, plume centerline. Adj for wind freq in N, NNE, NNW dirs, Bevelacqua 1999, p357.
 Fraction of yr exposed 1.000 8,760 hr/yr

Waywood Bulk Waste	Bulk Conc Ci/m3	Surface Conc Ci/m2	Site	Site	FGR #12 DCF-surf. Sv-m2/Bq-s	Site
			Boundary Air Conc Ci/m3	Boundary Grnd Con Ci/m2		Boundary Dose mrem/yr
Radionuclide						
Ra-226	7.89E-04	7.89E-07	1.13E-16	3.57E-11	6.44E-18	2.69E-05
Pb-214	7.89E-04	7.89E-07	1.13E-16	3.57E-11	2.44E-16	1.02E-03
Bi-214	7.89E-04	7.89E-07	1.13E-16	3.57E-11	1.41E-15	5.88E-03
Pb-210	7.89E-04	7.89E-07	1.13E-16	3.57E-11	2.48E-18	1.03E-05
Po-210	7.89E-04	7.89E-07	1.13E-16	3.57E-11	8.29E-21	3.46E-08
Ra-228+D	3.17E-03	3.17E-06	4.55E-16	1.43E-10	0.00E+00	0.00E+00
Ac-228	3.17E-03	3.17E-06	4.55E-16	1.43E-10	9.28E-16	1.56E-02
Th-228	3.17E-03	3.17E-06	4.55E-16	1.43E-10	2.35E-18	3.94E-05
Ra-224	3.17E-03	3.17E-06	4.55E-16	1.43E-10	9.57E-18	1.60E-04
Pb-212	3.17E-03	3.17E-06	4.55E-16	1.43E-10	1.43E-16	2.40E-03
Bi-212	3.17E-03	3.17E-06	4.55E-16	1.43E-10	1.79E-16	3.00E-03
Tl-208	1.14E-03	1.14E-06	1.64E-16	5.17E-11	2.98E-15	1.80E-02
Th-230	5.87E-04	5.87E-07	8.42E-17	2.66E-11	7.50E-19	2.33E-06
Th-232	3.17E-03	3.17E-06	4.55E-16	1.43E-10	5.51E-19	9.23E-06
U-234	5.87E-04	5.87E-07	8.42E-17	2.66E-11	7.48E-19	2.32E-06
U-235	2.70E-05	2.70E-08	3.87E-18	1.22E-12	1.48E-16	2.11E-05
Th-231	2.70E-05	2.70E-08	3.87E-18	1.22E-12	1.85E-17	2.64E-06
U-238	5.87E-04	5.87E-07	8.42E-17	2.66E-11	5.51E-19	1.71E-06
Th-234	5.87E-04	5.87E-07	8.42E-17	2.66E-11	8.32E-18	2.58E-05
Pa-234m	5.87E-04	5.87E-07	8.42E-17	2.66E-11	1.53E-17	4.75E-05
Projected Dose to Resident at Site Boundary (mrem/yr)						4.62E-02

W2 Surface water transport of ground-deposited dust to a low-lying area
 Based on ground deposited dust in Pathway S3

Operational time, Byproduct 30 yr

Projected Dose to Resident at Site Boundary over 30 year buildup time (mrem/yr) 1.39E+00

TOTAL DOSE DUE TO ALL PATHWAYS	Pathway	Dose Summary (mrem/yr)
Airborne dust from open byproduct waste cell	A1	8.04
Radon gas from uncovered active waste slope	A3a	0.07
Radon gas from byproduct waste with interim cover	A3b	0.00
External radiation from offsite soil (contaminated by dust deposition)	S3	0.05
Surface water transport of ground-deposited dust to a low-lying area	W2	1.39

TOTAL PROJECTED DOSE TO RESIDENT AT SITE BOUNDARY: 9.54

[HOME](#) [WISE Uranium Project](#) > [Calculators](#) >

Uranium Mill Tailings Cover Calculator

(last updated 2 Jul 2004)

Requires Netscape 3.0, Internet Explorer 3.0 or higher. JavaScript must be enabled.

For educational purposes only. No warranty.

Determine the radon flux through a multi-layer soil cover of an uranium mill tailings pile and/or optimize the cover for a given flux.

(For calculating radon flux from bare and/or water covered tailings, see the [Uranium Mill Tailings Radon Flux Calculator](#))

Select activity unit first, then enter the parameters and click the "Calculate" button below. [HELP](#)

Layer 1 is the tailings layer.

Numbers can be entered in exponential notation: $5 \cdot 10^{-6} = 5e-6$

Activity unit: pCi Bq

Sample Data Input Data							
Layer Data HELP <input type="checkbox"/>							
Layer No.	Thickness [m]	Ra-226 Activity Conc. [pCi/g]	Rn-222 Emanation Fraction	Porosity	Moisture Cont. [dry wt_%]	Fraction Passing #200 Mesh (75 μ m) *)	Rn-222 Eff. Diff.Coeff *) [m ² /s]
1	21.33	493	0.3	0.3	12		
2							
3							
4							
5							
6							
7							
8							
Options HELP <input type="checkbox"/>							
0 Entrance Radon flux to Layer 1 [pCi/m ² s] *)							

0	Surface Radon conc. at top of system [pCi/L] *)
0	Layer No. to be optimized *)
0	Surface flux constraint for optimization [pCi/m ² s] *)
0.01	Surface flux convergence criterion (fraction) *)
48.3	Annual Precipitation [cm] *)
198.12	Annual Lake Evaporation [cm] *)
45.72	Depth to Water Table [m] *)

*) optional

Calculate

Reset Form

HELP 

Results

----- Input Parameters -----

Number of Layers: 1
 Radon Flux into Layer 1: 0 pCi/m²s
 Surface Radon Concentration: 0 pCi/L
 Bare Source Flux (Jo) from Layer 1: 165.2 pCi/m²s
 Specific Bare Source Flux from Layer 1: 0.335 pCi/m²s per pCi_Ra-226/g

Layer No.	Thickness [m]	Ra-226 [pCi/g]	Emanat Fract	Porosity	Moisture [dry wt_%]	Diff Coeff [m ² /s]
1	21.33	493	0.3	0.3	12	166.3E-9

----- Results of Radon Diffusion Calculation -----

> See also:

- [Unit Converter](#)
- [Uranium Mill Tailings Radon Flux Calculator](#)
- [Uranium Radiation Properties · Uranium Radiation Exposure](#)
- [Uranium Decay Calculator](#)
- [Radon Individual Dose Calculator](#)
- [Uranium in Soil Individual Dose Calculator](#)
- [Uranium Mine and Mill Resident Individual Dose Calculator](#)
- [Nuclear Fuel Population Health Risk Calculator \(collective dose\)](#)

HOME WISE Uranium Project > Calculators >

[HOME](#) [WISE Uranium Project](#) > [Calculators](#) >

Uranium Mill Tailings Cover Calculator

(last updated 2 Jul 2004)

Requires Netscape 3.0, Internet Explorer 3.0 or higher. JavaScript must be enabled.

For educational purposes only. No warranty.

Determine the radon flux through a multi-layer soil cover of an uranium mill tailings pile and/or optimize the cover for a given flux.

(For calculating radon flux from bare and/or water covered tailings, see the [Uranium Mill Tailings Radon Flux Calculator](#))

Select activity unit first, then enter the parameters and click the "Calculate" button below. [HELP](#)

Layer 1 is the tailings layer.

Numbers can be entered in exponential notation: $5 \cdot 10^{-6} = 5e-6$

Activity unit: pCi Bq

Sample Data		Input Data					
Layer Data HELP <input type="checkbox"/>							
Layer No.	Thickness [m]	Ra-226 Activity Conc. [pCi/g]	Rn-222 Emanation Fraction	Porosity	Moisture Cont. [dry wt_%]	Fraction Passing #200 Mesh (75 μ m) *)	Rn-222 Eff. Diff.Coeff *) [m ² /s]
1	21.33	165.2	0.3	0.3	12		
2	.61	0	0	0.29	12		
3							
4							
5							
6							
7							
8							
Options HELP <input type="checkbox"/>							
0		Entrance Radon flux to Layer 1 [pCi/m ² s] *)					

0	Surface Radon conc. at top of system [pCi/L] *)
0	Layer No. to be optimized *)
0	Surface flux constraint for optimization [pCi/m ² s] *)
0.01	Surface flux convergence criterion (fraction) *)
48.3	Annual Precipitation [cm] *)
198.12	Annual Lake Evaporation [cm] *)
45.72	Depth to Water Table [m] *)
*) optional	

[HELP](#)

Results

----- Input Parameters -----

Number of Layers: 2
 Radon Flux into Layer 1: 0 pCi/m²s
 Surface Radon Concentration: 0 pCi/L
 Bare Source Flux (Jo) from Layer 1: 55.36 pCi/m²s
 Specific Bare Source Flux from Layer 1: 0.335 pCi/m²s per
 pCi_Ra-226/g

Layer No.	Thickness [m]	Ra-226 [pCi/g]	Emanat Fract	Porosity	Moisture [dry wt_%]	Diff Coeff [m ² /s]
1	21.33	165.2	0.3	0.3	12	166.3E-
2	0.61	0	0	0.29	12	108.9E-

> See also:

- [Unit Converter](#)
- [Uranium Mill Tailings Radon Flux Calculator](#)
- [Uranium Radiation Properties · Uranium Radiation Exposure](#)
- [Uranium Decay Calculator](#)
- [Radon Individual Dose Calculator](#)
- [Uranium in Soil Individual Dose Calculator](#)
- [Uranium Mine and Mill Resident Individual Dose Calculator](#)
- [Nuclear Fuel Population Health Risk Calculator \(collective dose\)](#)

[HOME](#) [WISE Uranium Project](#) > [Calculators](#) >