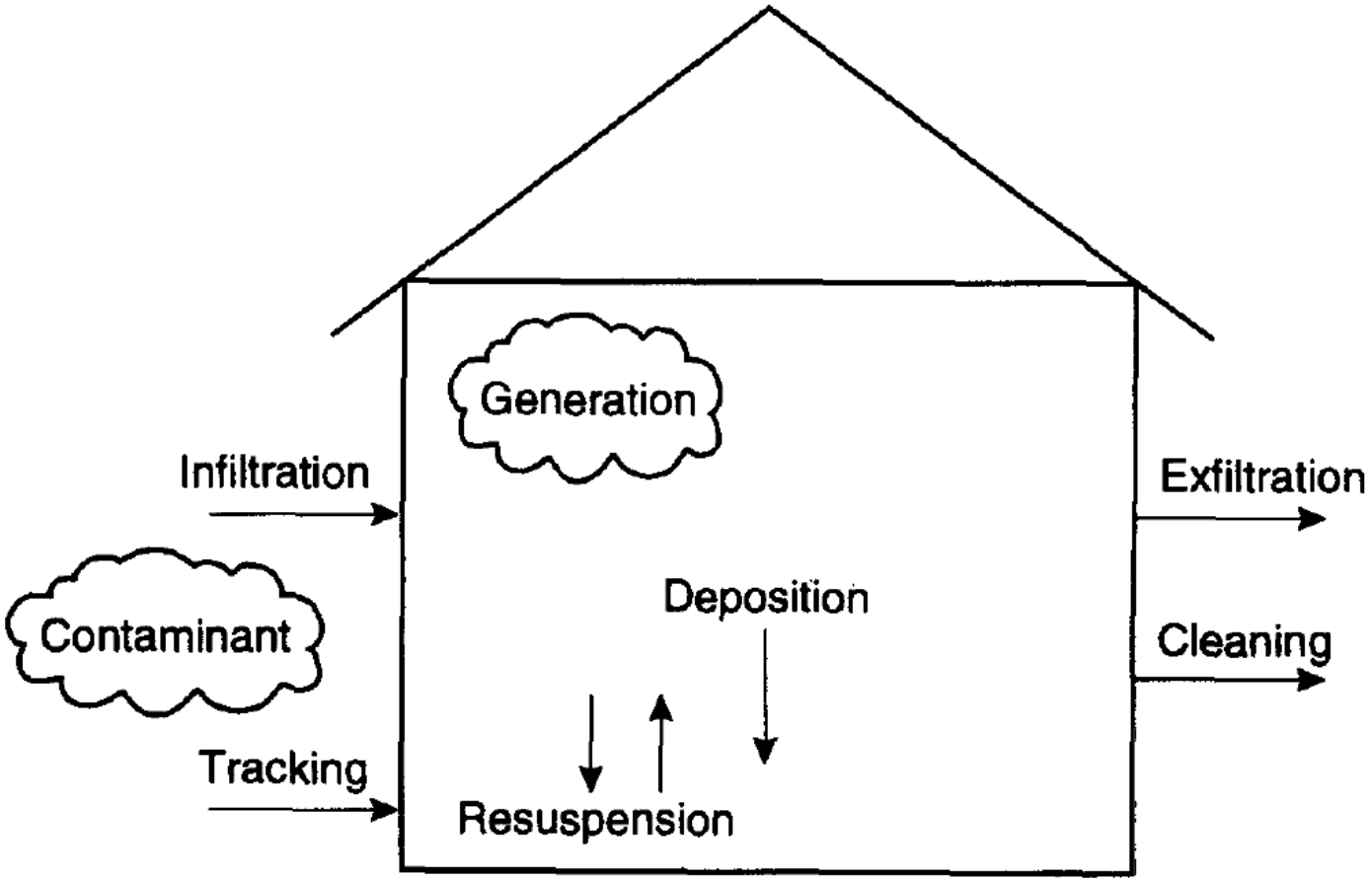
Alternative Model for the Calculation of Uranium Intakes at GSI

Prepared by

Robert Anigstein
S. Cohen & Associates

August 28, 2012



Contaminant Fate and Transport

Uranium Handling Times, Based on MCW Purchase Orders

Period covered by PO			Uranium handling	
Date		Hours[a]	Total (h)[b]	Fraction[c]
1/1/53[d]	2/28/58[d]			4.99%[e]
3/1/58	6/30/58	2928	125	4.27%
7/1/58	10/31/58	2952	112.5	3.81%
11/1/58	6/30/59	5808	225	3.87%
7/1/59	6/30/60	8784	337.5	3.84%
7/1/60	6/30/61	8760	337.5	3.85%
7/1/61	6/30/62	8760	437.5	4.99%
7/1/62	6/30/63	8760	125	1.43%
7/1/63	6/30/64	8784	28.12	0.32%
7/1/64	6/30/65	8760	28.12	0.32%
7/1/65	6/30/66	8760	12.86	0.15%

[a] Duration of period

[b] Total hours of uranium handling operations during specified time period

[c] Fraction of time devoted to uranium handling operations (column 4 ÷ column 3)

[d] No purchase orders found for this period

[e] Maximum of all later periods

Calculation of Surficial Uranium Concentrations

$$\frac{d\sigma_i}{dt} = -\mu\,\sigma_i + f_i R$$

σ_i = surficial uranium concentration due to accumulation during time period i (Bq/m^2)

t = time (d)

μ = fractional removal rate
= 6.7×10^{-4} d^{-1} (OTIB 70)

f_i = fraction of time during period i during which uranium handling operations occurred

R = rate of accumulation during uranium handling operations (Bq m^{-2} d^{-1})

Given that $\sigma_i(t_{i1}) = 0$:

$$\sigma_i(t) = \frac{f_i R}{\mu}\left(1 - e^{-\mu (t - t_{i1})}\right) \qquad (t_{i1} < t < t_{i2})$$

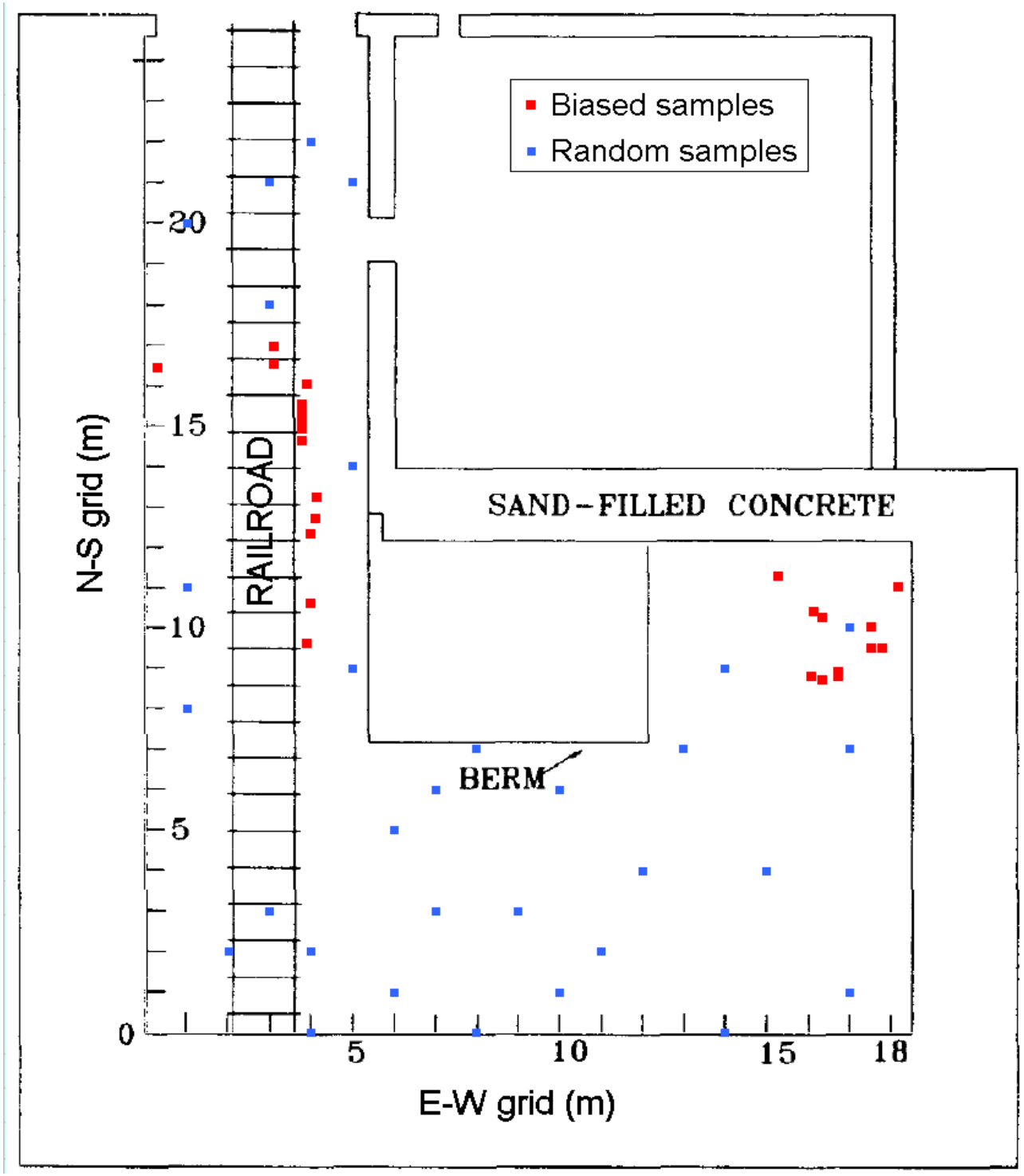
$$= \frac{f_i R\, e^{-\mu t}}{\mu}\left(e^{\mu t_{i2}} - e^{\mu t_{i1}}\right) \qquad (t_{i2} < t)$$

$$S(t) = \sum_{i}^{n(t)} \sigma_i(t)$$

$\sigma_i(t)$ = surficial uranium activity concentration at time t due to accumulation during time period i (Bq/m^2)

$S(t)$ = total surficial uranium activity concentration at time t (Bq/m^2)

$n(t)$ = number of uranium-handling time intervals up to time t



Locations of α-Activity Measurements in Old Betatron Building

Alpha Activity Concentrations on Floor of Old Betatron Building

Sample location		Alpha	
North	East	dpm/100 cm^2	Bq/m^{2a}
0	4	<MDA	42
0	8	<MDA	42
0	14	<MDA	42
1	6	<MDA	42
1	10	<MDA	42
1	17	<MDA	42
2	2	<MDA	42
2	4	<MDA	42
2	11	21	35
3	3	<MDA	42
3	7	35	58
3	9	<MDA	42
4	12	<MDA	42
4	15	<MDA	42
5	6	<MDA	42
6	7	<MDA	42
6	10	<MDA	42
7	8	<MDA	42
7	13	35	58
7	17	<MDA	42
8	1	<MDA	42
9	5	<MDA	42
9	14	<MDA	42
10	17	42	70
11	1	<MDA	42
14	5	28	47
18	3	<MDA	42
20	1	<MDA	42
21	3	<MDA	42
21	5	<MDA	42
22	4	<MDA	42
Average			43.6

[a] Calculated assuming "<MDA" = 25 dpm/100 cm^2

Rate of Accumulation of Surficial Uranium During Uranium Handling Operations

$$R = \frac{e^{\mu t_f}\ \mu\ S(t_f)}{\sum_{i}^{n(t_f)} f_i\left(e^{\mu t_{i2}} - e^{\mu t_{i1}}\right)}$$

R = rate of accumulation of surficial uranium during uranium handling operations
= 1,195 Bq m^{-2} d^{-1}

$S(t_f)$ = average α-activity concentration on first floor of Old Betatron Building at time t_f
= 43.6 Bq/m^2

t_f = time of ORNL survey
= 14,767 d (January 1, 1953–June 7, 1993)

Airborne Uranium Activity Concentrations

$$\chi_S(t) = F_r\, S(t)$$

$\chi_S(t)$ = airborne uranium activity concentration due to surficial contamination at time t

F_r = resuspension factor
= 1×10^{-5} m^{-1}

$$\chi_h = \frac{R}{v_d}$$

χ_h = airborne uranium activity concentration due to uranium handling activities
= 18.44 Bq/m^3
= 1,106 dpm/m^3

v_d = deposition velocity of 5 μm AMAD particles
= 7.5×10^{-4} m/s
= 64.8 m/d

Inhalation of Uranium by GSI Workers

Year	U concentration			Intake (dpm/calendar day)			
	Bq/m^{2}[a]	dpm/100 cm^{2}[a]	dpm/m^{3}[b]	Resuspension	U handling	Total	App BB
1953	10,119	6,071	6.07	64.87	1,591.28	1,656.15	111.57
1954	27,245	16,347	16.35	174.67	1,591.28	1,765.95	111.57
1955	40,657	24,394	24.39	260.65	1,591.28	1,851.93	111.57
1956	51,209	30,725	30.73	328.30	1,591.28	1,919.58	111.57
1957	59,402	35,641	35.64	380.82	1,591.28	1,972.10	111.57
1958	64,775	38,865	38.86	415.27	1,327.34	1,742.61	111.57
1959	65,559	39,336	39.34	420.30	1,229.22	1,649.52	111.57
1960	66,123	39,674	39.67	423.91	1,229.25	1,653.16	111.57
1961	66,682	40,009	40.01	427.49	1,410.92	1,838.41	128.07
1962	71,491	42,895	42.89	458.32	1,018.30	1,476.62	93.28
1963	61,489	36,893	36.89	394.20	276.89	671.09	26.05
1964	49,322	29,593	29.59	316.20	102.44	418.64	10.13
1965	39,887	23,932	23.93	255.72	74.30	330.02	7.66
1966	31,800	19,080	19.08	203.87	23.19	227.06	5.20
1967	24,902	14,941	14.94	159.64		159.64	0.932
1970	11,949	7,169	7.17	76.60		76.60	0.932
1973	5,733	3,440	3.44	36.76		36.76	0.932
1976	2,749	1,650	1.65	17.62		17.62	0.932
1979	1,321	793	0.79	8.47		8.47	0.932
1982	634	380	0.38	4.06		4.06	0.932
1985	304	182	0.18	1.95		1.95	0.932
1988	146	87	0.09	0.93		0.93	0.932
1991	70	42	0.04	0.45		0.45	0.932
1993[c]	46	28	0.03	0.29		0.29	0.932

[a] Surficial activity concentration

[b] Airborne activity due to resuspension from contaminated surface

[c] Intakes continued until July 10, 1993, the date remediation under FUSRAP was completed.

Plausibility Tests of Parameter Values

χ_h = derived airborne uranium activity concentration due to uranium handling activities
= 1,106 dpm/m^3

Handling of Uranium Rods at Melt Plant Building at Hanford

Operation	U concentration dpm/m^3
Unloading rods from truck with fork lift	3,926
Receiving rods: unloading truck and stacking rods	517
Loading straightened rods directly from table onto truck	88
Geometric mean	563

Calculation of Air Exchange as the Only Means of Removal

$$r = \frac{\mu}{F_r H}$$

r = air exchange rate in Old Betatron Building
= 0.26 h^{-1}

μ = fractional removal rate
= 6.7×10^{-4} d^{-1}
= 2.79×10^{-5} h^{-1}

F_r = resuspension factor
= 1×10^{-5} m^{-1}

H = height of shooting room in Old Betatron Building
= 35 ft = 10.7 m