Memorandum

Date: February 10, 2010

Subject: Technical Basis for Receipt Surveys for Radium-Scale Materials

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This memorandum serves to document the technical basis for exposure rate limits associated with the receipt of radium-scale containing wastes at the Clean Harbors Deer Trail (CHDT) facility.

A technical basis document was prepared by Dade Moeller and Associates (DMA) to describe the correlation between activity concentrations within contaminated piping and external exposure rates. However, the DMA guidance assumed that piping or other contaminated equipment would be transported without being containerized. In practice, this means of transport is unlikely; it is more reasonable to assume that contaminated piping and equipment would be placed in a roll-off container or end-dump truck for transport.

To prevent cross contamination and unnecessary handling of the contaminated materials, it is desirable for CHDT personnel to conduct verification surveys on the outside of shipping containers or received radium-scale wastes. Additional calculations are required to account for the attenuation of the gamma emissions from the radium scale by the shipping container, as well as from the buildup of scattered radiation. A range of measurements to account for the effects of shielding will be used by CHDT personnel to confirm that radiation levels on incoming radium-scale waste shipments are within CHDT waste acceptance criteria.

Calculations

Equation 10.17 of *Introduction to Health Physics* (Cember 1996) is as follows:

$$I = B \times I_O e^{-\mu x}$$

where:

I	=	gamma-ray intensity transmitted through an absorber of thickness x
B	=	buildup factor
I_O	=	gamma-ray intensity at zero absorber thickness
e	=	base of the natural logarithm system
μ	=	linear attenuation coefficient, cm^{-1}
x	=	thickness of absorber, cm

Both the buildup factor and the linear attenuation coefficient are functions of the absorber material and the incident gamma energy. Since the radium-containing materials evaluated using this the procedure are mostly in equilibrium with the gamma-emitting progeny, a weighted

average approach was used to determined the resulting beam intensity after interactions with two types of container materials – aluminum and steel (modeled as iron).

The gamma fluence modeling software Microshield was used to determine the energy composition of the gamma emissions from materials containing 75-percent radium-226 and 25-percent radium-228 following a one-year ingrowth period. The breakdown of gamma energies is shown in Table 1.

Table 1. Relative Contribution of Gamma Energies Associated with Radium Scale

Energy (MeV)	Percentage Contribution
0.04	0.003%
0.05	0.022%
0.06	0.007%
0.08	0.965%
0.1	0.165%
0.15	0.145%
0.2	1.794%
0.3	3.821%
0.4	5.794%
0.5	1.326%
0.6	12.148%
0.8	6.317%
1	25.242%
1.5	14.416%
2	19.562%
3	8.271%

As noted above, both the linear attenuation coefficient and buildup factors are functions of the incident energy. Published linear attenuation coefficients were found in Table 5.2 of Cember 1996, and additional values were found by graphing and extrapolating from the published values. The buildup factors aluminum and iron were obtained from Table 6.5.1, Exposure Buildup Factors, of the *Handbook of Health Physics and Radiological Health*, Third Edition (Shleien et al 1998). Thicknesses of 0.160 inches of aluminum (found to be a standard thickness for aluminum end-dump trailers) and 0.1345 inches of steel (equal to 10-gauge steel) were used in the calculation.

Using the linear attenuation coefficients, buildup factors, and relative contributions of gamma energies to the overall exposure, an overall intensity reduction (I/I_O) value was obtained for both aluminum and steel containers. Using the shielding intensity reduction, as well as accounting for the buildup of scattered radiation, exposure rate limits for measurements on the outside of the shipping containers were calculated and are presented in Table 2. It is assumed that the

Memorandum

containers are full, and that the confirmation measurements will be collected on or near contact with the outside of the shipping container.

Table 2. Container Exposure Rate Limits

	Non-Containerized Limit (µR/hr) (1)	Aluminum Container (µR/hr) (2)	Aluminum Container w/ Buildup (µR/hr) (2)	Steel Container (µR/hr) (2)	Steel Container w/ Buildup (µR/hr) (2)
Multiple < 4 inches	170 (3)	160	230	140	200
Multiple > 4 inches	230 (3)	210	320	190	280
Multiple Debris	170 (3)	160	230	140	200
Single < 4 inches	120 (4)	110	160	100	140
Single > 4 inches	150 (4)	140	210	130	180
Single Debris	120 (4)	110	160	100	140

1. µR/hr = microroentgens per hour.
2. Values are rounded to the nearest multiple of ten.
3. The generator limit for multiple pipes/pieces of debris is the average of nine measurements.
4. The generator limit for single pipes/pieces of debris is the maximum of nine measurements.

For example, based on the calculation, a shipment of pipe less than four inches in diameter determined by the generator to be in compliance with the CHDT acceptance criteria in a multiple pipe configuration with an average of 170 uR/hr or less, would be expected to have an average exposure rate of 160 uR/hr to 230 uR/hr (when accounting for the buildup of scattered radiation). Acceptance at the CHDT facility requires the collection and documentation of measurements within the limits listed on Table 2.

Conclusions

The limits shown in Table 2 will be used by CHDT personnel to verify that shipments of radium scale wastes meet the CHDT waste acceptance criteria. CHDT confirmation measurements will be collected with a Ludlum Model 19 exposure rate meter. Any measurements exceeding the ranges listed in Table 2 may require the shipment to be unloaded from the shipping container for further surveys, or may result in rejection of the load.

References

Cember 1996. *Introduction to Health Physics*, Third Edition. McGraw-Hill Health Professions Division, New York.

Schleien et al 1998. *Handbook of Health Physics and Radiological Health*, Third Edition. Williams & Wilkins, Baltimore, MD.

Memorandum

Attachment 1 – Intensity Calculations for Aluminum Container

Energy (MeV) (1)	% Energy Activity	μ (cm^{-1}) (2)	x (cm) (3)	I/Io (without buildup)	I/Io - weighted average	Buildup Factor (4)	I/Io (with buildup)	I/Io with buildup-weighted average
0.04	0.00%	0.489	0.41	0.82	0.00	2.04	1.672	0.00
0.05	0.02%	0.467	0.41	0.83	0.00	2.00	1.655	0.00
0.06	0.01%	0.450	0.41	0.83	0.00	1.97	1.641	0.00
0.08	0.97%	0.422	0.41	0.84	0.01	1.92	1.617	0.02
0.1	0.17%	**0.435**	0.41	0.84	0.00	**1.91**	1.601	0.00
0.15	0.15%	**0.362**	0.41	0.86	0.00	1.81	1.564	0.00
0.2	1.79%	**0.324**	0.41	0.88	0.02	1.76	1.545	0.03
0.3	3.82%	**0.278**	0.41	0.89	0.03	1.69	1.511	0.06
0.4	5.79%	0.266	0.41	0.90	0.05	1.64	1.474	0.09
0.5	1.33%	**0.227**	0.41	0.91	0.01	**1.57**	1.432	0.02
0.6	12.15%	0.226	0.41	0.91	0.11	1.57	1.434	0.17
0.8	6.32%	**0.185**	0.41	0.93	0.06	1.52	1.413	0.09
1	25.24%	**0.166**	0.41	0.93	0.24	1.45	1.355	0.34
1.5	14.42%	**0.135**	0.41	0.95	0.14	1.41	1.339	0.19
2	19.56%	**0.117**	0.41	0.95	0.19	**1.37**	1.306	0.26
3	8.27%	**0.096**	0.41	0.96	0.08	**1.33**	1.279	0.11
					0.93			**1.37**

1. MeV = mega electron volts.
2. cm^{-1} = per centimeter. Bolded values are published values from Table 5.2 of Cember 1996. Non-bolded values were determined by extrapolation .
3. cm = centimeter. An aluminum thickness of 0.160 inches (0.41 centimeters) was assumed.
4. Buildup factors from Table 6.5.1 of Schleien et al 1998, for mean free path (equal to the product of μx) of 0.5. Bolded values are published values. Non-bolded values were determined by extrapolation.

Memorandum

Attachment 2 – Intensity Calculations for Steel Container

Energy (MeV) (1)	% Energy Activity	μ (cm^{-1}) (2)	x (cm) (3)	I/Io (without buildup)	I/Io - weighted average	Buildup Factor (4)	I/Io (with buildup)	I/Io with buildup-weighted average (5)
0.04	0.003%	3.330	0.34	0.32	0.00		0.000	0.00
0.05	0.022%	2.912	0.34	0.37	0.00		0.000	0.00
0.06	0.007%	2.610	0.34	0.41	0.00		0.000	0.00
0.08	0.965%	2.196	0.34	0.47	0.00		0.000	0.00
0.1	0.165%	**2.720**	0.34	0.39	0.00	**1.26**	0.498	0.00
0.15	0.145%	**1.445**	0.34	0.61	0.00		0.000	0.00
0.2	1.794%	**1.090**	0.34	0.69	0.01		0.000	0.00
0.3	3.821%	**0.838**	0.34	0.75	0.03		0.000	0.00
0.4	5.794%	0.836	0.34	0.75	0.04		0.000	0.00
0.5	1.326%	**0.655**	0.34	0.80	0.01	**1.48**	1.183	0.02
0.6	12.148%	0.655	0.34	0.80	0.10		0.000	0.00
0.8	6.317%	**0.525**	0.34	0.84	0.05		0.000	0.00
1	25.242%	**0.470**	0.34	0.85	0.21	**1.41**	1.201	0.30
1.5	14.416%	**0.383**	0.34	0.88	0.13		0.000	0.00
2	19.562%	**0.335**	0.34	0.89	0.17	**1.35**	1.204	0.24
3	8.271%	**0.285**	0.34	0.91	0.08	**1.32**	1.198	0.10
					0.84			**1.20**

1. MeV = mega electron volts.
2. cm^{-1} = per centimeter. Bolded values are published values from Table 5.2 of Cember 1996 for iron. Non-bolded values were determined by extrapolation .
3. cm = centimeter. A steel thickness of 0.1345 inches (0.34 centimeters) was assumed.
4. Buildup factors from Table 6.5.1 of Schleien et al 1998, for mean free path (equal to the product of μx) of 0.5. Bolded values are published values. Based on the distribution of published values, additional values could not be extrapolated.
5. Only the gamma energies with published buildup factors were used in the determination of the weighted average.