Approved by:	General Manager	Radiation Safety Officer

STANDARD OPERATING PROCEDURE

15.RPP.05

ESTIMATION OF INHALATION DOSE

1.0 OBJECTIVE

To define specific methods and procedures for estimating the inhalation dose workers at the Clean Harbors Deer Trail (CHDT) landfill or other job sites from inhalation of airborne radioactive material.

2.0 SCOPE

This standard operating procedure (SOP) addresses the calculation of radionuclide intakes and committed effective dose equivalent (CEDE) for CHDT or other applicable workers and members of the general public for quarterly or annual reporting.

3.0 POLICY

Estimates of inhalation dose to CHDT landfill workers shall be conducted to verify that annual CEDE are below annual occupational limits per 10 CFR 20.1201 and maintained as low as reasonably achievable (ALARA).

4.0 RESPONSIBILITIES

Responsibilities of the CHDT Radiation Safety Officer (RSO), CHDT management, and other Clean Harbors staff are defined in the Radiation Protection Plan (SOP 15.RPP.01).

5.0 GENERAL PROCEDURE

5.1 Calculation of Radionuclide Intake

Corrected workplace airborne concentrations from radioactive materials shall be established, on a quarterly basis, from the airborne monitoring program, consistent with SOP 15.OPS.15, *Air Monitoring for Radioactive Materials*. Monthly or quarterly data, in units of picocuries (pCi) per cubic meter of air, shall be specific to work location and shall be corrected for background ambient concentrations.

For each worker who is potentially exposed to airborne radioactive materials, it is conservatively assumed that they spend their entire time working during a quarter (and during a year) exposed. For cases where an individual worker could have different onsite, the highest measured airborne concentrations shall be used in estimating individual radionuclide intakes.

The analytical results in picocuries (pCi) are converted to an air concentration as follows:

$$Concentration\left(\frac{\mu Ci}{ml}\right) = \frac{\text{Re}\,sult(pCi)}{\left(10^6\,\frac{pCi}{\mu Ci}\right)\times T(hr)\times\left(60\,\frac{\min}{hr}\right)\times F\left(\frac{cubic\ \ feet}{\min}\right)\times\left(28316.846592\,\frac{ml}{cubic\ \ feet}\right)}$$

where

T = sample collection time

F = average flow rate over the sample collection time

Once the estimated radionuclide mixtures and corrected airborne contamination levels are established, individual worker intake by inhalation can be estimated. The intake from inhalation of a radionuclide *i* is estimated using the following equation:

$$I_i = T \times Breathing\ Rate \times C_{a,i}$$

where: I_i = intake of radionuclide *i* by inhalation, pCi,

T = the duration of inhalation, hours,

Ventilation Rate = amount of air inhaled per time, cubic meters per hour, and

$C_{a,i}$ = concentration of radionuclide *i* in air, pCi per cubic meter (following a conversion from units of µCi/ml).

Based on information provided by the International Commission on Radiation Protection (ICRP) in Publication 66, the adult male ventilation rate during light exercise is 1.5 cubic meters per hour (ICRP 1993).

5.2 Calculation of Inhalation Dose

CEDEs to workers shall be calculation using the following equation:

$$H_{E,50} = \Sigma_i\, \Sigma\, W_T\, H_{T,50,i}$$

where: $H_{E,50}$ = the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the CEDE to each of these organs or tissues,

W_T = weighting factors for each specific body tissue or organ, and

$H_{T,50,i}$ = CEDE for radionuclide *i* (millirem).

The CEDE for radionuclide *i* ($H_{T,50,i}$) is found by multiplying the intake of each radionuclide (I_i) by the unit intake committed dose conversion factor for each radionuclide and tissue or organ ($DCF_{T,i}$) as shown in the following equation:

$$H_{T,50,i} = I_i \times DCF_{T,i}$$

To streamline the process, and for consistency with the doses recorded by the external dosimetry program, unit intake effective dose coefficients by radionuclide *i* (i.e., $DCF_{E,i} = \Sigma T\ DCF_{T,i}$, where T is for each tissue or organ) tabulated by the U.S. Environmental Protection Agency (EPA) shall be used. Modifying the above equations to account for the use of unit inhalation intake effective dose coefficients is shown in the following equation.

$$H_{E,50} = (T_w \times Breathing\ Rate)\ \Sigma_i\ (C_{a,i} \times DCF_{E,i})$$

The unit inhalation intake effective dose coefficients, taken from Federal Guidance Report No. 11 (Eckerman et al. 1988) are provided in Attachment 1 for the radionuclides of concern. These values are the most conservative (highest) across all solubility classes considered by the EPA.

6.0 RESPIRATORY PROTECTION:

The CHDT RCRA permit requires the use of respiratory protection for all activities when workers are in close proximity to the waste. These activities include sampling, treatment (when required), and in-cell disposal. Full-face air-purifying respirators are used by CHDT workers for these activities. Consistent with 6 CCR-1007-1, § 4.24 and Part 4 - Appendix A, a respiratory protection factor of 50 shall be applied to all appropriate work when the use of respirators is mandatory.

7.0 INHALATION DOSE WORKSHEET

An example worksheet for calculating inhalation CEDEs is provided in Attachment 2. The sum of the inhalation doses for each quarter is used to produce the annual inhalation dose estimate for each worker. This value is then added to the annual external dose for each worker to produce the estimated annual total CEDE. Similar calculations may be performed in a spreadsheet or using other means.

8.0 REFERENCES

10 CFR 20.1201. *Occupational Dose Limits for Adults.* Current Version.

Eckerman, K. F., A. B. Wolbarst, and A. C. B. Richardson. 1988. Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. Federal Guidance Report No. 11, EPA-520/1-88-020, U.S. Environmental Protection Agency, Washington, D.C.

International Commission on Radiation Protection (ICRP). 1993. Human Respiratory Tract Model for Radiological Protection. ICRP Publication 66, Annals of the ICRP, Vol. 23, Nos. 1-3.

ATTACHMENT 1 – UNIT INTAKE COMMITTED EFFECTIVE DOSE EQUIVALENT COEFFICIENTS

Radionuclides	$DCF_{E,i}$ [(a)] (seiverts/becquerel inhaled)	$DCF_{E,i}$ [(b)] (millirem/picocurie inhaled)
Uranium Series		
^{238}U	3.20E-05	1.18E-01
^{234}Th	9.47E-09	3.50E-05
^{234}U	3.58E-05	1.32E-01
^{230}Th	8.80E-05	3.26E-01
^{226}Ra	2.32E-06	8.58E-03
^{214}Pb	2.11E-09	7.81E-06
^{214}Bi	1.78E-09	6.59E-06
^{210}Pb	3.67E-06	1.36E-02
^{210}Bi	5.29E-08	1.96E-04
^{210}Po	2.54E-06	9.40E-03
Actinium Series		
^{235}U	3.32E-05	1.23E-01
^{231}Th	2.37E-10	8.77E-07
^{231}Pa	3.47E-04	1.28E+00
^{227}Ac	4.65E-04	1.72E+00
^{227}Th	4.37E-06	1.62E-02
^{223}Ra	2.12E-06	7.84E-03
^{211}Pb	2.35E-09	8.70E-06
Thorium Series		
^{232}Th	4.43E-04	1.64E+00
^{228}Ra	1.29E-06	4.77E-03
^{228}Ac	8.33E-08	3.08E-04
^{228}Th	9.23E-05	3.42E-01
^{224}Ra	8.53E-07	3.16E-03
^{212}Pb	4.56E-08	1.69E-04
^{212}Bi	5.83E-09	2.16E-05

(a) Based on data from Federal Guidance Report No. 11 (Eckerman et al. 1988).

(b) Converted from units of sievert per becquerel to units of millirem/picocurie by multiplying by a conversion factor of 3,700.

ATTACHMENT 2 – EXAMPLE DEER TRAIL WORKER QUARTERLY INHALATION WORKSHEET

Employee Name: _____ Payroll Number: _____ Reporting Period: _____ Date: _____

Estimated inhalation exposure duration for this worker during the reporting period	500 hours per Quarter	Respiratory protection used?	(Y/N)

Inhalation Dose Calculations:	**Column 1**	**Column 2**	**Column 3**	**Column 4**	**Column 5**
	Identified Radionuclides[1]	**Estimated Airborne Concentration by Radionuclide[2] (picocuries/cubic meter)**	**Estimated Intake by Radionuclide[3] (picocuries)**	**Unit Intake Inhalation Dose Conversion Factors[4] (millirem/picocurie)**	**Estimated CEDE[5] (millirem)**
				Total:	

Prepared by: _____ (Signature) Reviewed by: _____ (Signature)

[1] List the radionuclides reported by the analytical laboratory for the air sample with the highest reported activity to which this worker was exposed.
[2] Enter the corrected airborne concentration for this quarter, by radionuclide, from data collected per SOP 15.OPS.15, *Air Monitoring for Radioactive Materials*
[3] Multiply the entries in **Column 2** by a ventilation rate of 1.5 cubic meters per hour, and by 500 hours (per quarter).
[4] Insert the unit intake inhalation dose conversion factors from Attachment 1 in units of mrem/pCi inhaled.
[5] Multiply the entries in **Column 3** by the entries in **Column 4**, and divide by 50 if this worker used respiratory protection during the exposure. Total the entries in this column at the bottom of the column.