AIR PATHWAY DOSE MODELING FOR THE H-AREA TANK FARM

Eduardo B. Farfán

JANUARY 22, 2010
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Printed in the United States of America

Prepared For
U.S. Department of Energy
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Eduardo B. Farfán

JANUARY 22, 2010
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1/22/10

1/22/10

1/22/10

1/22/2010

1/28/2010
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LIST OF ACRONYMS

CAP88  The Clean Air Act Assessment Package-1988 (CAP-88). A Dose and Risk Assessment Methodology for Radionuclide Emissions to Air
DF    Dose Conversion Factors
DOE  U.S. Department of Energy
DRF  Dose-Release Factors
EDE  Effective Dose Equivalent
EPA  U.S. Environmental Protection Agency
HTF  H-Area Tank Farm
MEI  Maximally Exposed Individual
NESHAP  National Emission Standards for Hazardous Air Pollutants
SRS  US DOE Savannah River Site
1.0 ABSTRACT

Dose-release factors (DRFs) were calculated for potential atmospheric releases of C-14, Cl-36, H-3, I-129, Sb-125, Se-79, Sn-126, and Tc-99 from the H-Area Tank Farm (HTF). DRFs represent the dose to the receptor exposed to 1 Ci of the specified radionuclide being released to the atmosphere. Receptors at the SRS boundary, 100, 400, 800, 1,010, 1,170, 1,230, 1,480, 1,700, and 2,360 m from the source were evaluated assuming a point or area source where appropriate. These DRFs can be used to estimate flux rates for this facility to estimate the potential dose to an individual.
2.0 INTRODUCTION

Waste determination identified C-14, Cl-36, H-3, I-129, Sb-125, Se-79, Sn-126, and Tc-99 as potential radionuclides for atmospheric release from the H-Area Tank Farm (HTF) (Figure 1). The potential dose to an individual located at the SRS boundary (12,380 m), 100, 400, 800, 1,010\textsuperscript{a}, 1,170\textsuperscript{b}, 1,230\textsuperscript{b}, 1,480\textsuperscript{c}, 1,700\textsuperscript{b}, and 2,360\textsuperscript{d} m due to exposure to these radionuclides if released from the HTF can be estimated by application of radionuclide-specific dose-release factors (DRFs) (mrem Ci\textsuperscript{-1}) to estimated flux rates (Ci y\textsuperscript{-1}) at a particular time period. The methodology for estimating these DRFs for the HTF are described in this report.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{H-Area Tank Farm Conceptual Layout.}
\end{figure}

\textsuperscript{a} Seepline: McQueen Branch
\textsuperscript{b} Seepline: Fourmile Branch
\textsuperscript{c} Seepline: Crouch Branch
\textsuperscript{d} Seepline: Upper Three Runs
2.1 H-AREA TANK FARM OVERVIEW

Figure 1 illustrates the layout of the H-Area Tank Farm. The dimensions of the HTF are 2,111 ft by 827 ft. Therefore, the area of this facility is 1,745,797 ft$^2$ (162,190 m$^2$) (Waste Determination). For the purposes of this evaluation, the HTF was assumed be of a uniform shape. The determination of area vs. point source is shown in Table 1.

Table 1. H-Area Tank Farm Area/Point Source Determination.

<table>
<thead>
<tr>
<th>Receptor Locations (m)</th>
<th>Receptor Location (m) / Eff. Length (m)$^*$</th>
<th>Area Source (yes or no)$^{**}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.25</td>
<td>yes</td>
</tr>
<tr>
<td>400</td>
<td>0.99</td>
<td>yes</td>
</tr>
<tr>
<td>800</td>
<td>1.99</td>
<td>yes</td>
</tr>
<tr>
<td>1010</td>
<td>2.51</td>
<td>no</td>
</tr>
<tr>
<td>1170</td>
<td>2.91</td>
<td>no</td>
</tr>
<tr>
<td>1230</td>
<td>3.05</td>
<td>no</td>
</tr>
<tr>
<td>1480</td>
<td>3.67</td>
<td>no</td>
</tr>
<tr>
<td>1700</td>
<td>4.22</td>
<td>no</td>
</tr>
<tr>
<td>2360</td>
<td>5.86</td>
<td>no</td>
</tr>
<tr>
<td>SRS Boundary***</td>
<td>30.74</td>
<td>no</td>
</tr>
</tbody>
</table>

* Effective Length is 402.7 m.
** If the ratio Receptor Location/Effective Length is less than 2.5 is the source must be considered as an area source.
*** SRS Boundary = 12,380 m.

2.2 DOSE-RELEASE FACTORS

Dose-release factors (DRFs) in mrem Ci$^{-1}$ are estimated by modeling the effective dose equivalent (EDE) (mrem y$^{-1}$) assuming an annual atmospheric release source term (Ci y$^{-1}$) of the associated radionuclides. EDEs are modeled using the EPA computer code, CAP88 (Beres 1990) for demonstration of compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) (EPA 2006a) where appropriate. The DRFs are simply the ratio of the EDE to the release activity.

For H-Area, the EDEs, and therefore the DRFs, were estimated for the maximally exposed individual (MEI) located at 12,380 m, the site boundary (Farfán 2009), and at distances of 100, 400, 800, 1,010, 1,170, 1,230, 1,480, 1,700, and 2,360 m from the release point using the meteorological data for the 2002-2006 period (Farfán 2007). Point source DRFs were estimated for the MEI at the site boundary and 100, 400, 800, 1,010, 1,170, 1,230, 1,480, 1,700, and 2,360 m locations. For radionuclides not contained within the CAP88 library, surrogates were assigned based on similar radiological properties and the dose was estimated by applying the appropriate dosimetric properties to the surrogate’s relative air concentrations estimated by the model. Because of their size and close proximity to the source, area source DRFs were estimated for the receptor at 100, 400 and 800 meters (Table 1).
3.0 DOSE METHODS

3.1 CAP88 MODELING

CAP88 (Beres 1990) models the EDE to a receptor at a specified location by first estimating the relative average air concentration \((\chi/Q)\) of the released radionuclides and then applying the appropriate exposure parameters and dosimetric values to estimate pathway-specific doses. To estimate the \(\chi/Qs\), CAP88 accesses a site-specific five-year meteorological database that includes wind speed, wind direction, temperature, dew point, and horizontal and vertical turbulence intensities. The resultant relative air concentrations are used to estimate EDE for ingestion, inhalation, plume shine (air immersion), and ground shine exposure pathways for the MEI. In accordance with 40CFR61 (EPA 2006a), the MEI is assumed to be located at the nearest home, farm, business, or school and is assumed to eat vegetables, meat, and milk produced at that location.

For the HTF, 1 Ci of the radionuclides listed in Section 2.0 was assumed to be released from ground level and over a one year period. The 2002-2006 meteorological database for the H-Area (Kabela and Weber 2007; Farfán 2007) was used to disperse the releases to the MEI at the site boundary and at additional receptor locations assumed to be at 100, 400, 800, 1,010, 1,170, 1,230, 1,480, 1,700, and 2,360 m from the potential release location. For H-Area, the MEI at the site boundary is located at a distance of approximately 12,380 m in the north cardinal direction (Farfán 2007). Site- and pathway- specific parameters used in the CAP88 model to estimate the resultant EDEs are taken from Lee (2001).

CAP88 model results assuming a 1 Ci release of the radionuclides listed in Section 2.0 from the HTF are listed in Table 2. Radionuclides not contained within the CAP88 database (Cl-36 and Se-79) are not listed in Table 2 but are discussed in subsequent sections (Section 3.2).

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Receptor Location (m)</th>
<th>SRS Boundary**</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-14</td>
<td>3.7E-01 2.8E-02 7.6E-03 5.0E-03 3.9E-03 3.6E-03 2.6E-03 2.1E-03 1.2E-03 1.0E-04</td>
<td></td>
</tr>
<tr>
<td>H-3</td>
<td>7.7E-03 5.8E-04 1.6E-04 1.0E-04 8.0E-05 7.4E-05 5.4E-05 4.3E-05 2.5E-05 2.1E-06</td>
<td></td>
</tr>
<tr>
<td>I-129</td>
<td>5.5E+02 3.2E+01 7.7E+00 4.8E+00 3.6E+00 3.3E+00 2.3E+00 1.8E+00 9.3E-01 4.4E-02</td>
<td></td>
</tr>
<tr>
<td>Sb-125</td>
<td>1.1E+01 8.8E-01 2.7E-01 1.8E-01 1.5E-01 1.4E-01 1.0E-01 8.3E-02 5.2E-02 6.3E-03</td>
<td></td>
</tr>
<tr>
<td>Sn-126*</td>
<td>4.8E+02 4.0E+01 1.2E+01 8.3E+00 6.6E+00 6.1E+00 4.7E+00 3.8E+00 2.4E+00 2.9E-01</td>
<td></td>
</tr>
<tr>
<td>Te-99</td>
<td>2.9E+00 2.4E-01 7.3E-02 5.0E-02 4.0E-02 3.7E-02 2.8E-02 2.3E-02 1.4E-02 1.7E-03</td>
<td></td>
</tr>
</tbody>
</table>

* Includes progeny
** SRS Boundary = 12,380 m.
3.2 RADIONUCLIDES NOT CONTAINED IN CAP88

Two of the radionuclides listed in Section 2.0 are not contained within the CAP88 library (Cl-36 and Se-79). Therefore, atmospheric transport was assumed to be equivalent to that of surrogate radionuclides with similar radiological properties (Table 3).

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Half-Life (y)</th>
<th>Surrogate</th>
<th>Surrogate Half-Life (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl-36</td>
<td>3.01E+05</td>
<td>Sn-126</td>
<td>2.30E+05</td>
</tr>
<tr>
<td>Se-79</td>
<td>2.95E+05</td>
<td>Sn-126</td>
<td>2.30E+05</td>
</tr>
</tbody>
</table>

EDEs for these radionuclides were estimated by applying their pathway-specific dosimetric properties to the surrogate’s \( \chi/Q \) estimated by the model. For ease, this was accomplished by applying a ratio of the dose coefficients to the surrogate EDEs estimated by the model. For example, the EDEs for Se-79 are estimated as follows:

\[
EDE_{\text{Se-79}} = EDE_{\text{Se-79}}^{\text{ing}} \cdot \frac{DF_{\text{Se-79}}^{\text{ing}}}{DF_{\text{Sn-126}}^{\text{ing}}} + EDE_{\text{Se-79}}^{\text{inh}} \cdot \frac{DF_{\text{Se-79}}^{\text{inh}}}{DF_{\text{Sn-126}}^{\text{inh}}} + EDE_{\text{Se-79}}^{\text{plume}} \cdot \frac{DF_{\text{Se-79}}^{\text{plume}}}{DF_{\text{Sn-126}}^{\text{plume}}} + EDE_{\text{Se-79}}^{\text{ground}} \cdot \frac{DF_{\text{Se-79}}^{\text{ground}}}{DF_{\text{Sn-126}}^{\text{ground}}}
\]

where,

- \( DF_{\text{ing}} \) = ingestion dose conversion factors from EPA (1988) (mrem pCi\(^{-1}\))
- \( DF_{\text{inh}} \) = inhalation dose conversion factors from EPA (1988) (mrem pCi\(^{-1}\))
- \( DF_{\text{plume}} \) = air immersion dose conversion factors from EPA (1993) (rem hr\(^{-1}\) per \( \mu \)Ci cm\(^{-3}\))
- \( DF_{\text{ground}} \) = ground surface dose conversion factors from EPA (1993) (rem hr\(^{-1}\) per \( \mu \)Ci cm\(^{-2}\))

EDEs for the radionuclides in Table 3 based on this methodology are listed in Table 4.

<table>
<thead>
<tr>
<th>Receptor Location (m)</th>
<th>100</th>
<th>400</th>
<th>800</th>
<th>1010</th>
<th>1170</th>
<th>1230</th>
<th>1480</th>
<th>1700</th>
<th>2360</th>
<th>SRS Boundary **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl-36*</td>
<td>7.9E-01</td>
<td>6.2E-02</td>
<td>1.8E-02</td>
<td>1.2E-02</td>
<td>9.5E-03</td>
<td>8.8E-03</td>
<td>6.6E-03</td>
<td>5.3E-03</td>
<td>3.2E-03</td>
<td>3.4E-04</td>
</tr>
<tr>
<td>Se-79*</td>
<td>1.1E+00</td>
<td>8.5E-02</td>
<td>2.6E-02</td>
<td>1.7E-02</td>
<td>1.4E-02</td>
<td>1.3E-02</td>
<td>9.7E-03</td>
<td>7.8E-03</td>
<td>4.8E-03</td>
<td>5.7E-04</td>
</tr>
</tbody>
</table>

* Based on Sn-126 surrogate relative air concentration.
** SRS Boundary = 12,380 m.

3.3 AREA SOURCE ESTIMATES

CAP88 models area sources for releases where the receptor distance/source effective length ratio is less that 2.5 (EPA 2006b). Based on the source dimensions in Table 1, the H-Area
Tank Farm must be treated as an area source when considering receptor distances of 100, 400, and 800 m. However, CAP88 Version 1.0 is deemed inappropriate close to the source (distance/diameter ratio is less than 1.3) as stated in Moore et al. (1979) and it does not handle area sources (Beres 1990). Therefore, point source and area source sector-average relative air concentration were estimated as described by Simpkins and Lee (2006).

The estimated point source area concentration \( (\chi/Q) \) of 8.1E-4 s m\(^{-3}\) calculated in Simpkins and Lee (2006) was compared to the area source sector-average relative air concentrations for the HTF to estimate the point/area source ratio for a receptor location of 100 m. Similar calculations were performed for 400 and 800 m, which resulted in an estimated point source area concentration \((\chi/Q)\) of 5.9E-5 s m\(^{-3}\) and 1.7E-05 s m\(^{-3}\), respectively. The area source average air concentrations and point/area source ratios are listed in Table 5. The point/area sources are conservatively rounded down to the nearest integer to roughly represent the overestimate of the average air concentration that would result from assuming a point source. These factors are applied to the CAP88 modeled 100, 400, and 800 m point source estimate to determine estimate area source EDEs for the HTF. Area source estimates for the HTF are listed in Table 6.

<table>
<thead>
<tr>
<th>Receptor Distance (m)</th>
<th>Point Source ( \chi/Q ) (s m(^{-3}))</th>
<th>Area Source (s m(^{-3}))</th>
<th>Point/Area Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>8.1E-04</td>
<td>1.7E-05</td>
<td>46</td>
</tr>
<tr>
<td>400</td>
<td>5.9E-05</td>
<td>2.6E-06</td>
<td>22</td>
</tr>
<tr>
<td>800</td>
<td>1.7E-05</td>
<td>1.6E-06</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 5. Area to Point Source Comparisons.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Receptor Location (m)</th>
<th>100</th>
<th>400</th>
<th>800</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-14</td>
<td></td>
<td>8.1E-03</td>
<td>1.3E-03</td>
<td>7.6E-04</td>
</tr>
<tr>
<td>Cl-36(^{*})</td>
<td></td>
<td>1.7E-02</td>
<td>2.8E-03</td>
<td>1.8E-03</td>
</tr>
<tr>
<td>H-3</td>
<td></td>
<td>1.7E-04</td>
<td>2.6E-05</td>
<td>1.6E-05</td>
</tr>
<tr>
<td>I-129</td>
<td></td>
<td>1.2E+01</td>
<td>1.5E+00</td>
<td>7.7E-01</td>
</tr>
<tr>
<td>Sb-125</td>
<td></td>
<td>2.3E-01</td>
<td>4.0E-02</td>
<td>2.7E-02</td>
</tr>
<tr>
<td>Se-79(^{*})</td>
<td></td>
<td>2.3E-02</td>
<td>3.9E-03</td>
<td>2.6E-03</td>
</tr>
<tr>
<td>Sn-126(^{*})</td>
<td></td>
<td>1.1E+01</td>
<td>1.8E+00</td>
<td>1.2E+00</td>
</tr>
<tr>
<td>Te-99</td>
<td></td>
<td>6.4E-02</td>
<td>1.1E-02</td>
<td>7.3E-03</td>
</tr>
</tbody>
</table>

\(^{*}\) Not in CAP88 database. Based on Sn-126 surrogate \( \chi/Q \)
\(^{**}\) Includes progeny.
4.0 RESULTS AND CONCLUSIONS

As described in Section 2.2 DRFs are merely the ratio of the EDE to the annual release activity. Because the model was executed assuming 1 Ci release, these DRFs are equal to the appropriate estimated EDEs. DRFs for the receptor located at the site boundary (12,380 m). Additional receptor locations were also considered: 100, 400, 800, 1,010, 1,170, 1,230, 1,480, 1,700, and 2,360 m from the HTF are listed in Table 7. These factors can be applied to expected release values from each disposal unit to estimate the potential dose to an individual located at each location.
Table 7. Atmospheric DRFs (mrem Ci\(^{-1}\)) for the H-Area Tank Farm\(^a\).

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>100 *</th>
<th>400 *</th>
<th>800 *</th>
<th>1010 **</th>
<th>1170 **</th>
<th>1230 **</th>
<th>1480 **</th>
<th>1700 **</th>
<th>2360 **</th>
<th>SRS Boundary ** ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-14</td>
<td>8.1E-03</td>
<td>1.3E-03</td>
<td>7.6E-04</td>
<td>5.0E-03</td>
<td>3.9E-03</td>
<td>3.6E-03</td>
<td>2.6E-03</td>
<td>2.1E-03</td>
<td>1.2E-03</td>
<td>1.0E-04</td>
</tr>
<tr>
<td>Cl-36****</td>
<td>1.7E-02</td>
<td>2.8E-03</td>
<td>1.8E-03</td>
<td>1.2E-02</td>
<td>9.5E-03</td>
<td>8.8E-03</td>
<td>6.6E-03</td>
<td>5.3E-03</td>
<td>3.2E-03</td>
<td>3.4E-04</td>
</tr>
<tr>
<td>H-3</td>
<td>1.7E-04</td>
<td>2.6E-05</td>
<td>1.6E-05</td>
<td>1.0E-04</td>
<td>8.0E-05</td>
<td>7.4E-05</td>
<td>5.4E-05</td>
<td>4.3E-05</td>
<td>2.5E-05</td>
<td>2.1E-06</td>
</tr>
<tr>
<td>I-129</td>
<td>1.2E+01</td>
<td>1.5E+00</td>
<td>7.7E-01</td>
<td>4.8E+00</td>
<td>3.6E+00</td>
<td>3.3E+00</td>
<td>2.3E+00</td>
<td>1.8E+00</td>
<td>9.3E-01</td>
<td>4.4E+02</td>
</tr>
<tr>
<td>Sb-125</td>
<td>2.3E-01</td>
<td>4.0E-02</td>
<td>2.7E-02</td>
<td>1.8E-01</td>
<td>1.5E-01</td>
<td>1.4E-01</td>
<td>1.0E-01</td>
<td>8.3E-02</td>
<td>5.2E-02</td>
<td>6.3E-03</td>
</tr>
<tr>
<td>Sc-79****</td>
<td>2.3E-02</td>
<td>3.9E-03</td>
<td>2.6E-03</td>
<td>1.7E-02</td>
<td>1.4E-02</td>
<td>1.3E-02</td>
<td>9.7E-03</td>
<td>7.8E-03</td>
<td>4.8E-03</td>
<td>5.7E-04</td>
</tr>
<tr>
<td>Sn-126****</td>
<td>1.1E+01</td>
<td>1.8E+00</td>
<td>1.2E+00</td>
<td>8.3E+00</td>
<td>6.6E+00</td>
<td>6.1E+00</td>
<td>4.7E+00</td>
<td>3.8E+00</td>
<td>2.4E+00</td>
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</tr>
<tr>
<td>Tc-99</td>
<td>6.4E-02</td>
<td>1.1E-02</td>
<td>7.3E-03</td>
<td>5.0E-02</td>
<td>4.0E-02</td>
<td>3.7E-02</td>
<td>2.8E-02</td>
<td>2.3E-02</td>
<td>1.4E-02</td>
<td>1.7E-03</td>
</tr>
</tbody>
</table>

* Calculated as area sources.
** Calculated as point sources.
*** SRS Boundary = 12,380 m.
**** Not in CAP88 database. Based on Sn-126 surrogate $\chi/Q$.
***** Includes progeny.

\(^a\) The DRF values shown were estimated based on EPA (1988 and 1993).
5.0 REFERENCES


Air Pathway Dose Modeling for the H-Area Tank Farm

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