This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

Modeling an Atmospheric Release as an Area Source in Support of Waste Disposal at the Savannah River Site

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Abstract: The Saltstone Facility was designed at the Savannah River Site (SRS) to treat and dispose of certain low-level liquid radioactive wastes. The final product of Saltstone is several large concrete vaults. As part of the performance assessment for Saltstone, reduction of dose to receptors downwind of the vaults have been estimated for treating the vaults as an area atmospheric source as opposed to a point source. The CAP88 model has the ability to handle area sources, but the methods are not appropriate for receptors close to the source such as these modeled at 100 m. Use of the area source as opposed to the point source can reduce the dose by as much as a factor of 5 depending on vault size.

INTRODUCTION

The Saltstone Facility was designed at the Savannah River Site (SRS) to treat and dispose of certain low-level liquid radioactive wastes. The Saltstone Facility receives by product low-level waste from stored waste tanks on site as well as from the effluent treatment facility that processes other tank farm wastes. The salt solution received at the Saltstone Facility for processing is mixed with cement, fly ash, and furnace slag to form a grout which is pumped into large concrete vaults called cells which are 30 m by 30 m and 7.6 m tall. These vaults can contain either 6 or 12 cells that will be covered with concrete, a clay cap and then backfilling with earth. Over long periods time radioactive contaminants could be released to the atmosphere from the concrete and this potential release is discussed here.

METHODS

Doses can be estimated using CAP88 (Beres 1990) which is used to demonstrate compliance with 40CFR61 (U.S. EPA 2003), National Emission Standards for Hazardous Air Pollutants (NESHAP). CAP88 has the ability to handle area sources, but the model is not deemed to be appropriate close to the source as stated in Moore et al. (1979): '… caution should be exercised when applying the area-source treatment where the ratio of the distance from the center (to the receptor) to the diameter of the source is less than 1.3.' For the large areas considered here (183 m by 30 m for 6 cells in Vault 1 and 183 m by 61 m for 12 cells in Vault 4), the methodology within CAP88 for handling area sources is not considered appropriate.

Air concentration calculations were performed independent of CAP88 for a point versus area source for average meteorological conditions, and the ratio of these two can be used as a rough approximation as to how much the dose would decrease due to the area release. This approach is approximate in that set annual average meteorological conditions were assumed rather than the annual average as determined by the actual joint frequency distribution that is used within the CAP88 model.

For a point source, the sector-average relative air concentration is estimated using the following Gaussian plume equation (U.S. NRC 1977):

$$\frac{\chi}{Q} = \frac{2.032}{\sigma_z x U} \exp\left[-\frac{1}{2} \left(\frac{H}{\sigma_z} \right)^2 \right]$$

where

χ/Q	sector-average relative air concentration (s m^{-3})
σ_z	vertical diffusion coefficient (m)
x	downwind distance (m)
U	wind speed at the release height (m s^{-1})
H	height of the release (m)

Assuming average meteorological conditions (D stability class, 4.5 m s^{-1} wind speed) as specified by the U.S. Department of Energy (U.S. DOE 1997) and a ground-level release, the air concentration can be estimated. The vertical diffusion coefficient at 100 m is estimated using Pasquill Briggs diffusion coefficients (Moore et al. 1979) as follows:

$$\sigma_z = 0.06x(1+0.0015x)^{-0.5} = 0.06(100)[1+0.0015(100)]^{-0.5} = 5.6 \text{ m}$$

The sector-average concentration for a point source associated with this average weather conditions would then be

$$\frac{\chi}{Q} = \frac{2.032}{\sigma_z x U}\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] = \frac{2.032}{5.6\times 100\times 4.5}\exp\left[-\frac{1}{2}\left(\frac{0}{5.6}\right)^2\right] = 8.1\times 10^{-4} \text{ s m}^{-3}$$

For an area source that is square with length 2a with sides parallel and perpendicular to the wind direction, the sector-average concentration at 100 m can be estimated by (Napier 2002):

$$\frac{\chi}{Q} = \int_{-a}^{a} \frac{1}{area \times \sqrt{2\pi}\sigma_z(r-\zeta)U} G(z,\zeta)d\zeta$$

where

area area of the release (m^2)

a 0.5 x length (m)

$\sigma_z(r-\zeta)$ vertical diffusion coefficient at distance $r-\zeta$ (m) *r* distance from the center of the release – note for 100 m from the edge of the contaminated area this number is 100+a (m)

ζ variable of integration (m)

$G(z,\zeta)$ vertical factor which is 1 for this case since the release is ground level

z vertical distance of the release above ground (m)

All other terms have been previously defined.

This equation can be integrated using numerical integration such as Simpson's Rule (Beyer 1981). The dimensions of the releases were roughly 30 m by 183 m and 61 m by 183 m. Using conservation of area, these rectangles are converted to squares with side lengths of 75 m and 106 m for Vaults 1 and 4, respectively.

RESULTS

For Vault 1, numerical integration of the above equation leads to a concentration estimate of 1.6×10^{-4} s m^{-3} that is roughly a factor of 5 less than the point source estimate of sector-average concentration of 8.1×10^{-4} s m^{-3} calculated above. Using this estimate, doses at 100 m from the edge of Vault 1 should be conservatively reduced by a factor of three to account for an area source. For Vault 4, numerical integration of this equation leads to a concentration estimate of $1.0x10^{-4}$ s m^{-3} that is roughly a factor of 8 less than the point source estimate of sector-average concentration of $8.1x10^{-4}$ s m^{-3} calculated above. Using this estimate, doses at 100 m from the edge of Vault 4 should be conservatively reduced by a factor of five to account for an area source. These conservatisms were included to account for the fact that actual meteorological data were not used. The use of average meteorology is an assumption and estimates could be refined using actual meteorological joint frequency distribution data.

CONCLUSIONS

Modeling atmospheric releases as an area source as opposed to a point source can have significant effect on resulting doses especially close in to the release location. For large vault areas the reduction in dose at 100 m could be up to a factor of 5. Methods such as these are gross approximations of atmospheric releases and should be treated as such. This methodology for an area source deviates from the approved NESHAP model and therefore, additional approval may be required before using it. Use of the area source provides a more realistic estimate of dose to receptors that are close to the release locations.

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