Atmospheric Dispersion Modeling for Carbon-14 Emissions

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Abstract

In June 2009, the Nuclear Regulatory Commission published Regulatory Guide 1.21, Revision 2, which included Carbon-14 (C-14) as a radionuclide of interest. Regulatory Guide 1.21 provided regulatory guidance to implement the requirements of 10 CFR 50.36a that operating procedures be developed for the control of effluents and that quantities of principal radionuclides be reported.

The dominant exposure pathway for C-14 is via ingestion. The dose modeling in Regulatory Guide 1.109 for C-14 (in the form of CO_2) assumes uptake in plants will occur while photosynthesis is occurring (growing season daylight hours).

The initial consensus was that confining atmospheric dispersion modeling to the daylight hours during the growing season would result in lower atmospheric dispersion factors than using the entire annual meteorological database. This is based on the general theory that day time periods should have more unstable conditions and more mixing of the atmosphere leading to lower atmospheric dispersion factors.

This assumption was tested using meteorological data from several nuclear power plant sites. Atmospheric dispersion modeling for both shoreline and inland sites was performed for elevated, ground-level, and mixed-mode release types. Results indicate that the height of release influences whether the use of daylight hours during the growing season in atmospheric dispersion modeling will result in lower atmospheric dispersion factors or not. This may be the result of increased unstable conditions that produce more incidences of looping plumes, which in turn transport the elevated emissions to the surface and increase the ground-level concentration. There were no apparent differences noted in the results from shoreline and inland sites.

Atmospheric Dispersion Modeling

AREVA computer codes AEOLUS-2 and AEOLUS-3 were used to model atmospheric dispersion at three shoreline and three inland sites. Site-specific meteorological data were used. Elevated, ground-level, and mixed-mode (plume treated as a ground-level release part of the time, treated as an elevated release part of the time, and something in between the two part of the time) release types were considered. Time periods considered were:

- Annual; and
- Daylight hours during the growing season.

Results

Sector-average atmospheric dispersion factors were compared on two bases:

- Maximum point with maximum point, i.e., not necessarily the same downwind sector and distance from the release point; and
- Maximum point (annual average) with same point (growing season), i.e., the same downwind sector and distance from the release point.

The maximum point is defined as the location of the highest sector-average atmospheric dispersion factor. The maximum point with maximum point comparison is a comparison of the highest sector-average atmospheric dispersion factors from the two runs, one using the annual average meteorological data, and one using the growing season daylight only hours, regardless of the receptor location. The maximum point with the same point comparison is a comparison of the highest sector-average atmospheric dispersion factor from the run using the annual meteorological data with the factor from the run using the growing season daylight only hours, at the same receptor location.

The comparisons are illustrated in Figure 1.

Maximum Point with Maximum Point Comparison

For five out of six elevated releases the daylight hours during the growing season meteorological period **did not** produce the lowest atmospheric dispersion values. For five out of six ground-level releases the daylight hours during the growing season meteorological period **did** produce the lowest atmospheric dispersion values. For three out of six mixed-mode releases the daylight hours during the growing season meteorological period **did** produce the lowest atmospheric dispersion values. There were no apparent differences noted in the results from shoreline and inland sites.

Maximum Point with Same Point Comparison

For five out of six elevated releases the daylight hours during the growing season meteorological period **did not** produce the lowest atmospheric dispersion values. For six out of six ground-level releases the daylight hours during the growing season meteorological period **did** produce the lowest atmospheric dispersion values. For four out of six mixed-mode releases the daylight hours during the growing season meteorological period **did** produce the lowest atmospheric dispersion values. There were no apparent differences noted in the results from shoreline and inland sites.

Summary

The initial consensus was that confining atmospheric dispersion modeling to the daylight hours during the growing season would result in lower atmospheric dispersion factors than using the entire annual meteorological database. Atmospheric dispersion modeling results indicate that the height of release influences whether the use of daylight hours during the growing season in atmospheric dispersion modeling will result in lower atmospheric dispersion factors or not.

One explanation for these results is that more unstable conditions in the atmosphere lead to more incidences of looping plumes (Figure 2), which transport the emissions to the surface and increase the ground-level concentration. This would explain why the elevated release type rarely leads to lower atmospheric dispersion values using the daylight hours during the growing season meteorological period, the mixed-mode release type leads to lower atmospheric dispersion values using the daylight hours during the growing season meteorological period about half of the time, and the ground-level release type almost always leads to lower atmospheric dispersion values using the daylight hours during the growing season meteorological period (since for ground-level releases, the plume is assumed to be in contact with the ground). There were no apparent differences noted in the results from shoreline and inland sites.

Figure 1

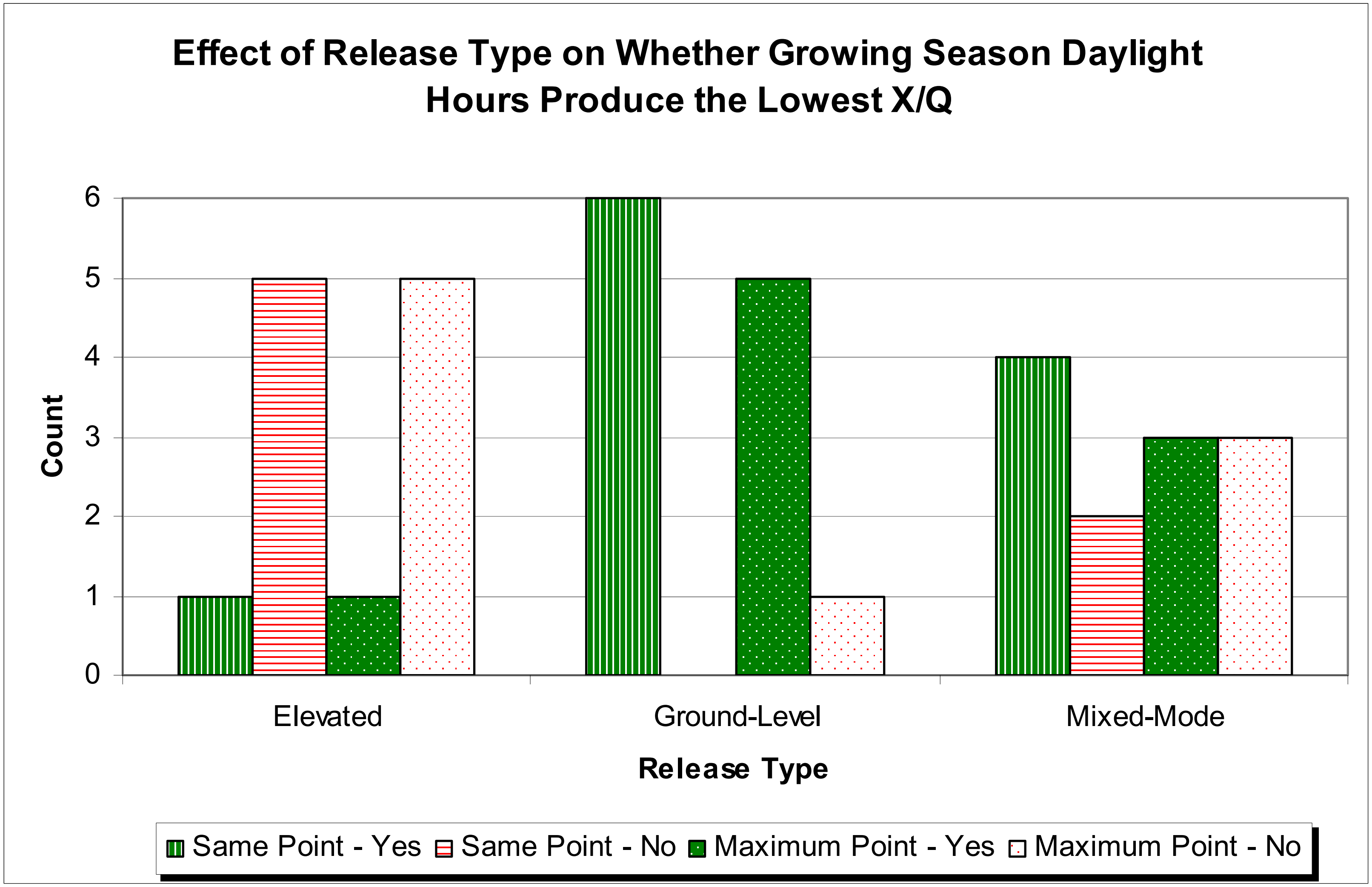
Effect of Release Type on Whether Growing Season Daylight Hours Produce the Lowest X/Q
Count
6
5
4
3
2
1
0
Elevated
Ground-Level
Mixed-Mode
Release Type
Same Point - Yes
Same Point - No
Maximum Point - Yes
Maximum Point - No

Figure 2