SHINE dispersion factor analysis for the proposed Netherlands EU therapeutics facility site

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Preparer:

Introduction

Doses to the public from emergency emission scenarios at the SHINE Europe Tx facility require some calculations that include plume dispersion dynamics. Instead of doing complex modeling to do these calculations, the emergency dose calculations often use conservative and simplified equations involving an atmospheric dispersion factor (ADF) χ/Q.

For the purposes of the SHINE Europe Tx facilities hazard assessment, the maximum ADF value is of interest because it represents the worst-case scenario that would result in the highest dose to the public. This worst-case ADF for the facility was calculated primarily using United States' Department of Energy (DOE) guidance.

ADF Calculation Methodology

The ADF depends on the weather conditions that are present at the time of the aerial release and the distance from the source to the person/location of interest. Because of this, the ADF is both location and time dependent. To estimate the ADF, the DOE Handbook provides a simplified Gaussian plume dispersion model [1]. While they provide a detailed ADF equation as a function of the relative cartesian distances from the source, the handbook also provides a worst-case ADF equation that assumes the person/location of interest is on the plume centerline; this results in the highest possible doses. This conservative equation can be found in Equation 1.

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where

Art. 5.1 lid 1 onder c Art.5.1 lid 2 onder f

This equation requires the wind speed and horizontal and vertical spreads of the plume as inputs. These spreads are dependent on the distance from the source and the weather conditions, primarily the atmospheric stability. There are seven distinct stability classes as defined by Pasquill-Gifford-Turner (P-G-T). They range from class A, which represents an extremely unstable atmosphere that normally occurs during bright sunshine and relatively low wind speeds, to class G, which represents an extremely stable atmosphere that normally occurs at night or early morning with light to zero wind speed.

The handbook provides many different empirically based parameterizations for estimating the spread of the plume. The parameterization that was selected for use in this analysis was the one from Eimutis and Konicek (EK). It was chosen because it provides reliable results for distances of less than 100 meters, and this parameterization is widely used by the United Stated Nuclear Regulatory Commission. Additionally, it was the only parameterization that predicts values for a P-G-T atmospheric stability class of G; the most potentially dangerous stability class in terms of dose. The equation and parameters of the EK can be found in Equation 2 and Table 1. For the horizontal spread (σ_y), b_y= 0.9031 and c_y= 0 for any distance and atmospheric stability [1].

$$\sigma_y(r) = a_y * r^{b_y} + c_y$$

$$\sigma_z(r) = a_z * r^{b_z} + c_z$$

where

$$r = downwind\ distance\ of\ the\ receptor\ from\ the\ point\ of\ release\ [m]$$

$$\sigma_y = standard\ deviation\ of\ the\ horizontal\ Gaussian\ distribution\ [m]$$

$$\sigma_z = standard\ deviation\ of\ the\ vertical\ Gaussian\ distribution\ [m]$$

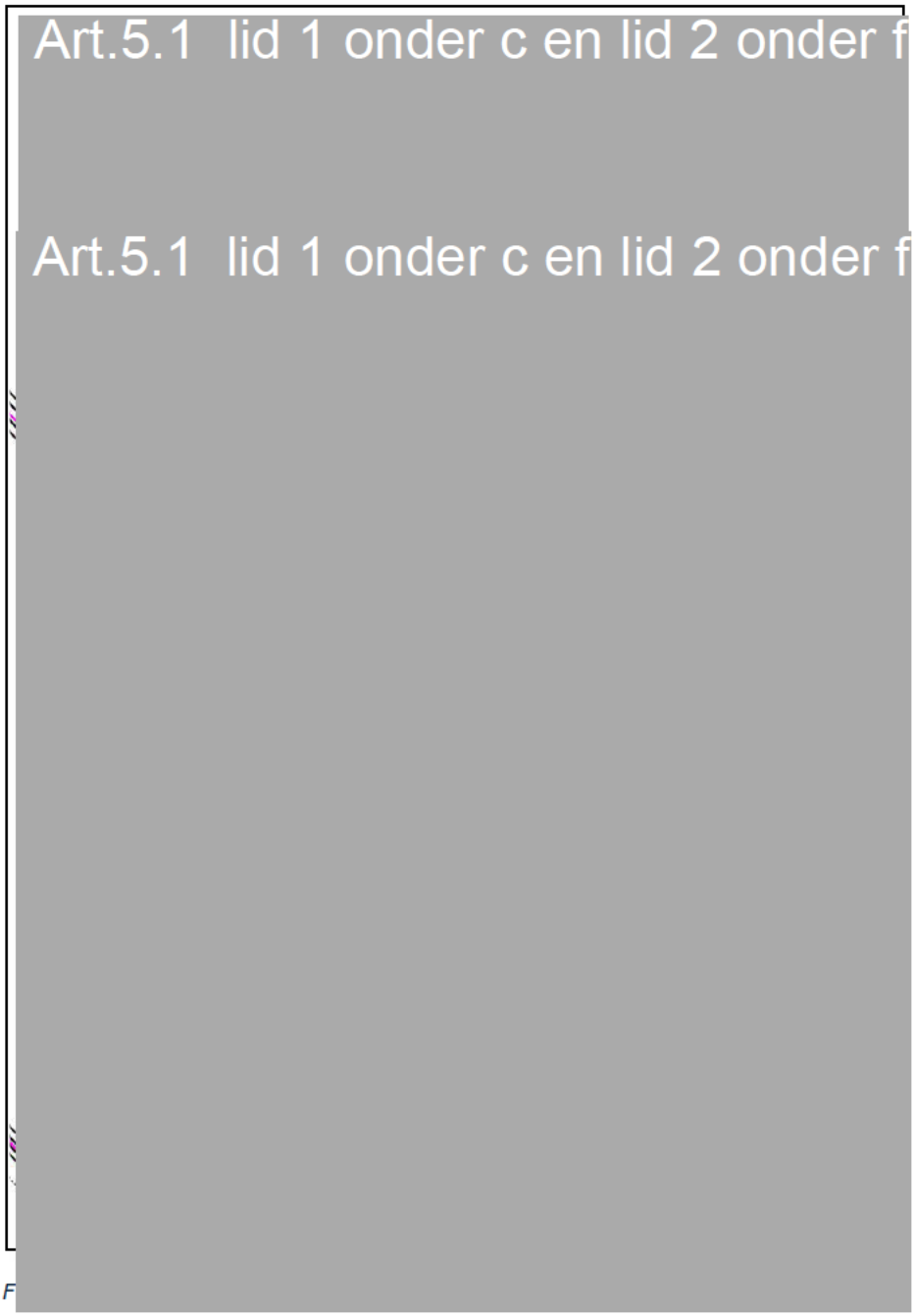
Equation 2: Eimutis and Konicek plume spread parameterization [1].

Table 1: Eimutis and Konicek plume spread parameterization coefficients by downwind radius and atmospheric stability [1]

		ATMOSPHERIC STABILITY CLASS						
	Distance	**A**	**B**	**C**	**D**	**E**	**F**	**G**
a_y	all	0.3658	0.2751	0.2089	0.1471	0.1046	0.0722	0.0481
a_z	< 100 m	0.192	0.156	0.116	0.079	0.063	0.053	0.032
	100 to 1000 m	0.00066	0.0382	0.113	0.222	0.211	0.086	0.052
	>1000 m	0.00024	0.055	0.113	1.26	6.73	18.05	10.83
b_z	< 100 m	0.936	0.922	0.905	0.881	0.871	0.814	0.814
	100 to 1000 m	1.941	1.149	0.911	0.725	0.678	0.74	0.74
	>1000 m	2.094	1.098	0.911	0.516	0.305	0.18	0.18
c_z	< 100 m	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	100 to 1000 m	9.27	3.3	0.0	-1.7	-1.3	-0.35	-0.21
	>1000 m	-9.6	2.0	0.0	-13.0	-34.0	-48.6	-29.2

Worst-Case ADF

The SHINE-Europe Tx facility has a complex site boundary. The site and building location can be seen below in Figure 1.



For this analysis, the location of the stack that will be emitting potential radionuclides is assumed to be in the center of the building. Using this assumption, the closet a member of the public can get to this stack is 58 meters. This distance corresponds with the location that could receive the maximum public dose.

The ADF was calculated for a variety of wind-speeds and stabilities to determine what combination yields the worst ADF factors. The DOE Handbook and other requirement documents do not provide guidance as to how to handle minimum wind-speed. This is

important because Equation 1 goes to infinity as the wind-speed goes to zero. For this analysis, it is assumed that the minimum wind speed will be 0.5 m/s. Historical weather from the nearest airport to Veendam, Eelde, was also analyzed to get a general sense of the probabilities of these various weather combinations [2]. These results are displayed in Figure 2. The ADF values for these various weather conditions were then calculated using Equation 1 and are displayed in Figure 3.

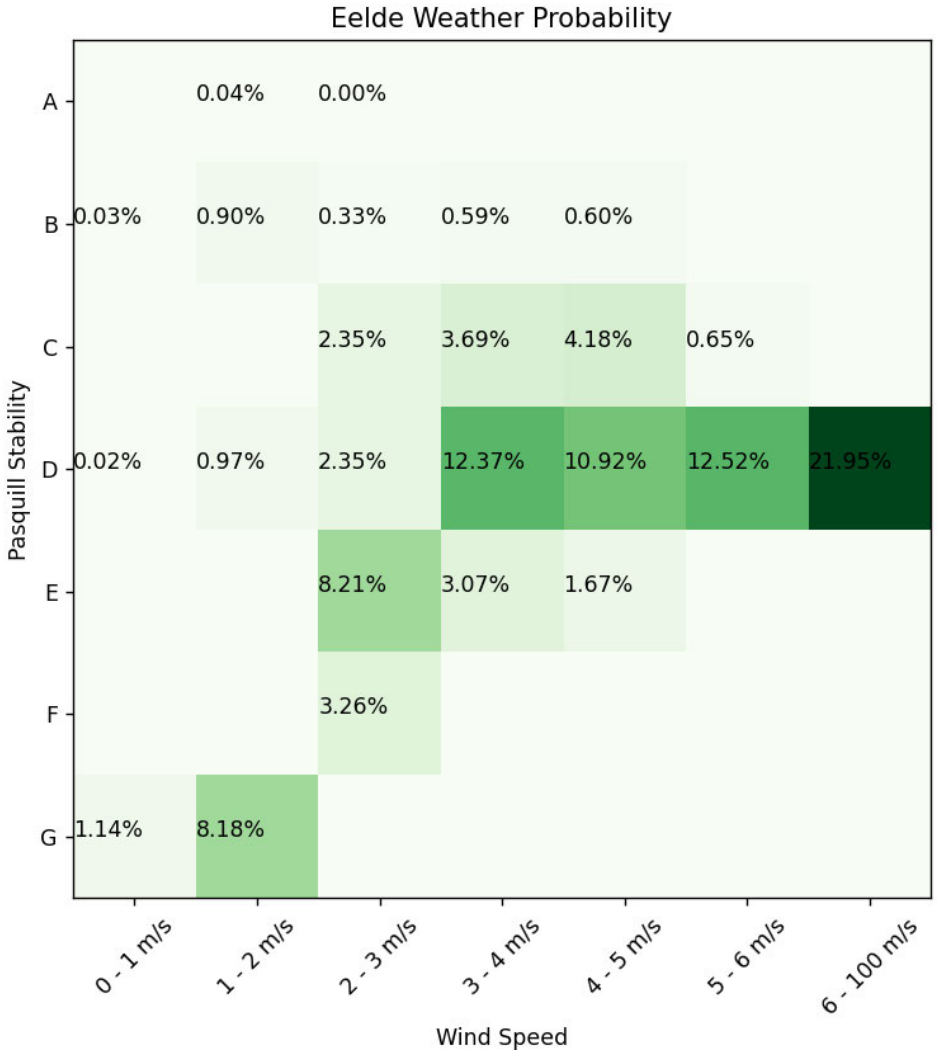


Figure 2: Historical probability of various weather conditions at the Eelde airport [2].

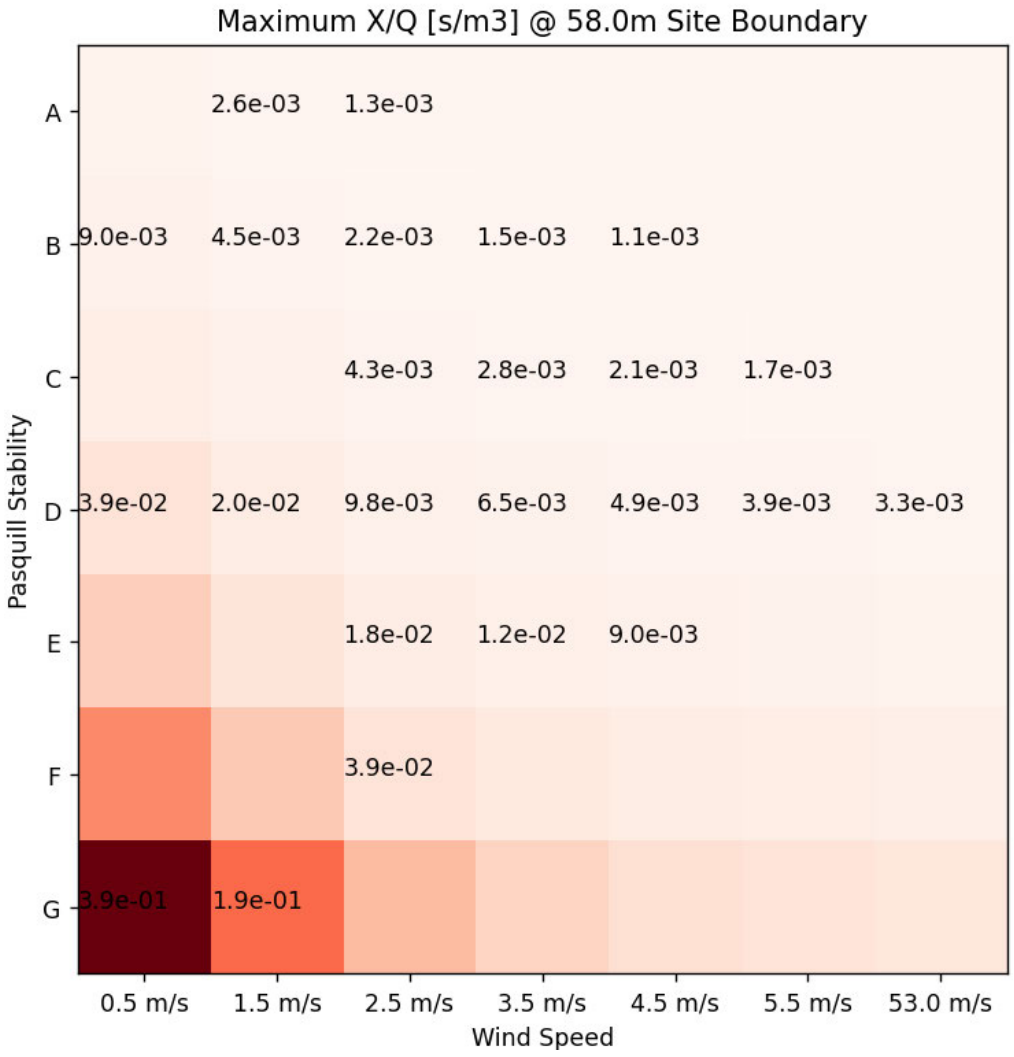


Figure 3: ADF values at 58 m from the exhaust stack for various weather conditions.

The highest ADF is 3.9e-1 s/m^3 and occurs during weather with a Pasquil Stability of G and low wind speed of 0.5 m/s. For more insight, Stability G weather conditions can only occur right around sunrise or sunset when the atmosphere is most stable. These conditions are relatively rare in the Veendam area, however, this ADF should be used as a bounding value for hazard calculations. It is also important to note that this analysis does not consider the wind directions at all. The 58 meter location that is being analyzed here will only be exposed to radionuclides when the wind is blowing the stack emissions southwest. So, if some analysis on what a median or specific percentile ADF is to the public during an average year, more intensive analysis will need to be done that considers the wind directions, exhaust plume width, and geospatial site-boundary.

References

[1] U.S. Department of Energy, "DOE Handbook Hazard and Accident Analysis Handbook," 2018.

[2] Koninklijk Nederlands Meteorologisch Instituut, "Hourly Eelde Weather Station Observations," 2024. [Online]. Available: https://daggegevens.knmi.nl/klimatologie/uurgegevens.