Investigations of MACCS2 for LANL Dispersion Analysis

DOE Workshop
Germantown, MD
June 5-6, 2012

Raymond F. Sartor, Ph.D.
Safety Basis - Technical Services
Los Alamos National Laboratory

Basic Equation for Ground-Level Release

$$\chi\left(x, y = 0, z = 0, H = 0\right) = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}} \left(1 + 2 \sum_{n=1}^{5} \left\{ \exp\left[-2 \left(\frac{nL}{\sigma_z} \right)^2 \right] \right\} \right)$$

Note:

1. The mixing layer term (in curly brackets) could be ignored for most LANL applications, especially for onsite receptors.

2. σ_y and σ_z are two critical parameters in estimating χ/Q.

Tadmor and Gur Equations

$$\sigma_y(x) = a_i \; x^{b_i}$$

$$\sigma_z(x, z_0) = \left(\frac{z_0}{3\,cm}\right)^{0.2} c_i x^{d_i}$$

Notes: surface roughness z_0 at LANL = 38 cm

Stability Class	a_i	b_i	c_i	d_i
A	0.3658	0.9031	0.00025	2.125
B	0.2751	0.9031	0.0019	1.6021
C	0.2089	0.9031	0.2	0.8543
D	0.1474	0.9031	0.3	0.6532
E	0.1046	0.9031	0.4	0.6021
F	0.0722	0.9031	0.2	0.602

Direct Measurements of Dispersion Coefficients with Draxler Method

$$\sigma_y = \sigma_\theta x F_y\left(\frac{x}{\bar{u}t_y}\right) \approx \sigma_v t F_y\left(\frac{t}{t_y}\right)$$

$$\sigma_z = \sigma_\emptyset x F_z\left(\frac{x}{\bar{u}t_z}\right) \approx \sigma_w t F_z\left(\frac{t}{t_z}\right)$$

where

σ_v = S.D. of transverse or crosswind wind speed [m/s]

σ_w = S.D. of vertical wind speed at effective release height [m/s]

t = downwind traveling time [s] = x/u

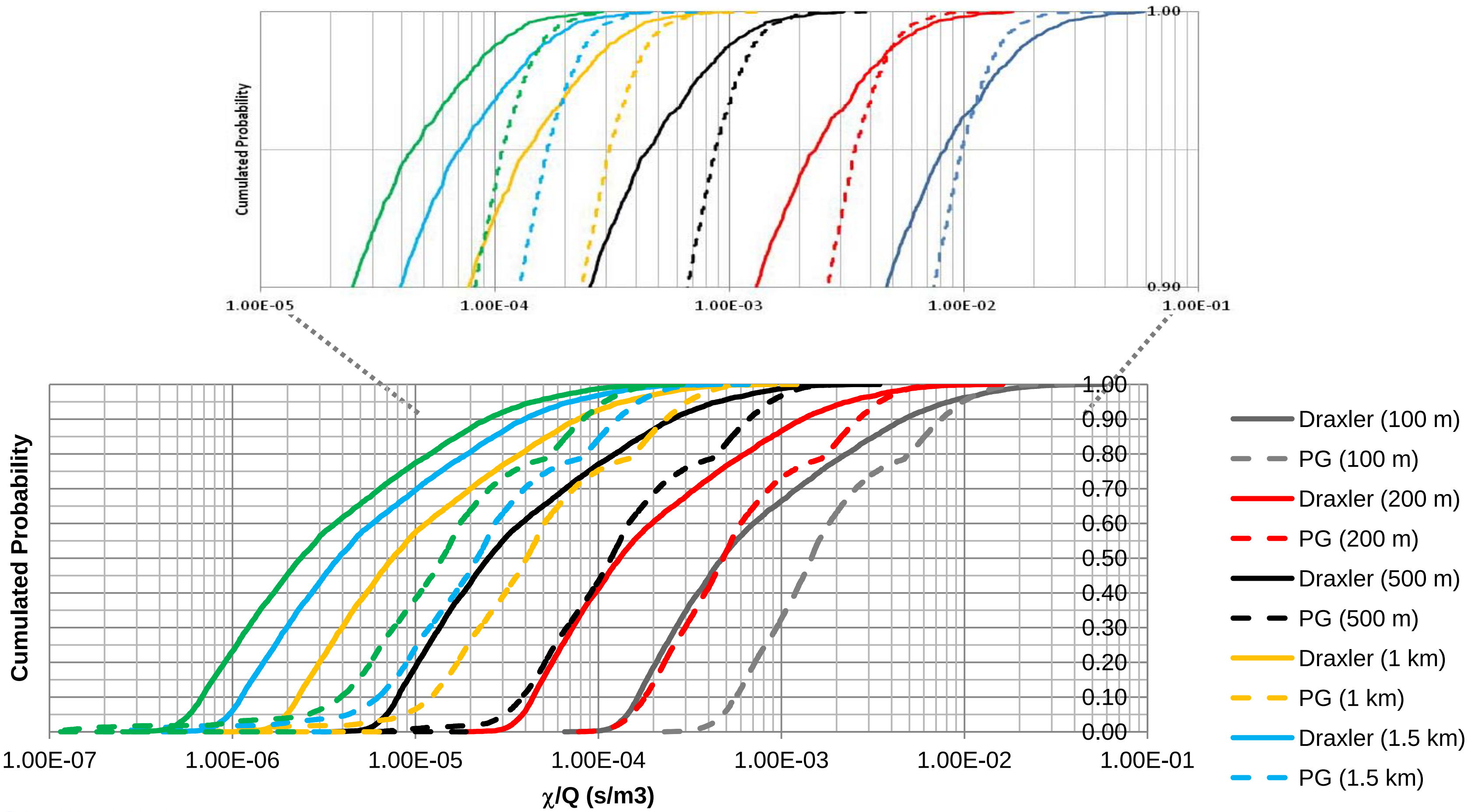
x = downwind distance at [m]

u = average downwind speed effective release height [m/s]

F_y = transverse universal function = $(1+0.90\sqrt{t/5000})^{-1}$ (Bowen 1994)

F_z = transverse universal function = $(1+0.90\sqrt{t/1000})^{-1}$ (Bowen 1994)

Cumulative Probability of χ/Q at Various Downwind Distances



Note: Based on TA6 2007 meteorological data

95th Percentile χ/Q –Bowen vs. PG

Correlation	Downwind (m)					
	100	200	500	1000	1500	2000
Bowen/T-G	0.85	0.67	0.51	0.45	0.43	0.41

- The ratios can be considered as adjustment factors of the LANL site-specific turbulence to the generic turbulence conditions by MACCS2.
- For offsite receptors, MACSS2 over-predicts at least a factor of two.

Conservatism of MACCS2

- Conservatism from simplified algorithms and generic equations for air dispersion
- The conservation become more significant for longer downwind distance, e.g., offsite receptors.
- Over-conservatism on dispersion analysis leads to overly conserved radiological dose, which may result unreasonably control and/or mitigation cost.

Alternative Dispersion Analysis for Offsite Receptor

- For offsite general public, AERMOD could be a good candidate. AERMOD is a next generation air dispersion model based on planetary boundary theory, and is adopted by EPA as a preferred model since 2005.
- AERMOD improves the estimation of dispersion coefficients similar to the Draxler's formula discussed in this paper.
- In addition to advanced meteorological turbulence, AERMOD also includes the PRIME building downwash algorithms, advanced depositional parameters, and local terrain effects.
- Overall, the advanced capacity of AERMOD should provide better confidence in accuracy of offsite public doses and reduce unreasonably conservative control and mitigation cost.

Deficiency of MACCS2 for Onsite Worker

- MACCS2 is not well suited for modeling dispersion close to the source (e.g., less than 100 meters and building wakes)
- Inflexibility of yearly data requirement on meteorological inputs (requires only single year of meteorological data with complete hourly records).
- Inflexibility to diverse configurations of release and receptor.

Alternative of Dispersion Analysis for Onsite Receptors

- ARCON96
  - A Gaussian dispersion code with building wake/cavity algorithms validated by wind tunnel studies and lateral plume meander validated by field tracer measurements.
  - It is the result of many years of NRC sponsored studies conducted by PNNL evaluating the Murphy-Campe models using experimental data and developing alternative approaches.
  - In many cases, especially for sites with a high frequency of very stable light wind speed conditions, ARCON96 has provided a marked reduction in χ/Q values compared to the traditional Murphy-Campe models.

Alternative of Dispersion Analysis for Onsite Receptors

- The flexibility of meteorological data input and statistically validated building wake/cavity algorithms allow reasonable estimates for many onsite worker scenarios.
- ARCON96 was used by the Yucca Mountain Project for onsite worker safety analyses of many nuclear facility complex configurations and accident scenarios.