

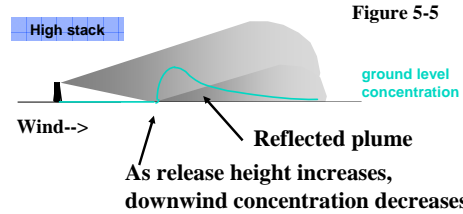
Atmospheric stability

Table 5-1 Atmospheric Stability Classes for Use with the Pasquill-Gifford Dispersion Model^{1,2}

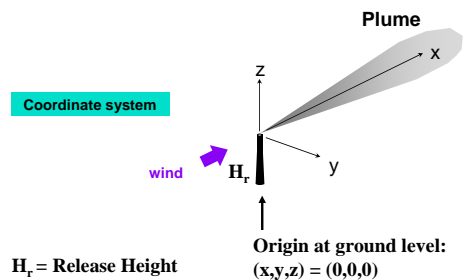
Surface wind speed (m/s)	Daytime insolation ³			Nighttime conditions ⁴	
	Strong	Moderate	Slight	Thin overcast or >4/8 low cloud	≤3/8 cloudiness
<2	A	A-B	B	F ⁵	F ⁵
2-3	A-B	B	C	E	F
3-4	B	B-C	C	D ⁶	E
4-6	C	C-D	D ⁶	D ⁶	D ⁶
>6	C	D ⁶	D ⁶	D ⁶	D ⁶

See qualifying notes below table!

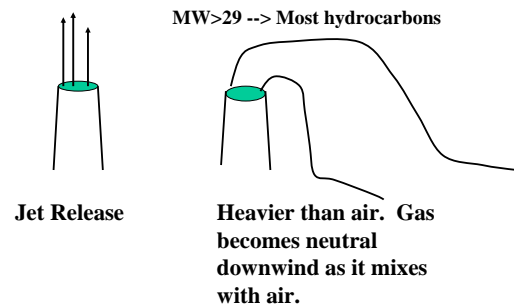
Release Height Effect



Coordinate systems



Release Momentum and Buoyancy



Dispersion Models

Dispersion models are based on a mass balance.

Two approaches:

1. Use eddy diffusivities, K , to represent turbulence.

Advantage: nice tidy theoretical model.

Disadvantage: $K = K(x,y,z)$, and impossible to measure.

See text.

2. Use dispersion coefficients which represent the standard deviations in the concentration profiles.

Advantage: easy to measure and correlate.

Gaussian form of plume equation Equation 5-49

$$\langle C \rangle(x, y, z) = \frac{Q_m}{2\pi\sigma_y\sigma_z u} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \times \left\{ \exp\left[-\frac{(z-H_r)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+H_r)^2}{2\sigma_z^2}\right] \right\}$$



$\langle C \rangle(x, y, z)$ = Ave. conc. (20-30 min ave)

Q_m = Release rate (mass/time)

σ_y, σ_z = Dispersion coefficients = f(stability class, downwind distance)

u = Wind speed (length/time)

y, z = Coordinates (length)

H_r = Release height (length)

Atmospheric stability

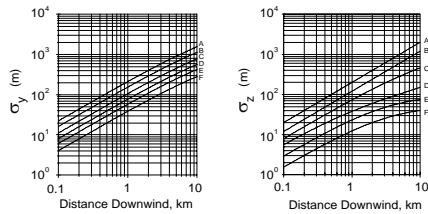


Fig. 5-10

Dispersion coefficients for plume model for rural releases. See Figure 5-11 for urban releases, and Table 5-2 for plume equations. Figure 5-12 and Table 5-3 are for puff model.

Simplified Cases - Plume

Ground Centerline Concentration: x

$$\langle C \rangle (x, 0, 0) = \frac{Q_m}{\pi \sigma_y \sigma_z u} \exp \left[-\frac{1}{2} \left(\frac{H_r}{\sigma_z} \right)^2 \right] \quad (5-51)$$

Ground, centerline, release height $H_r = 0$

$$\langle C \rangle (x, 0, 0) = \frac{Q_m}{\pi \sigma_y \sigma_z u} \quad (5-48)$$

x is implicit in the dispersion coefficients!

Maximum Concentrations - Plume

Always occurs at release point.

For releases above ground, max. concentration on ground occurs downwind.

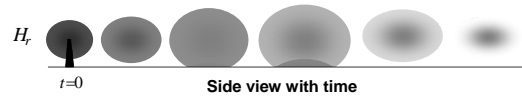
$$\left(\sigma_z \right)_{x, \max} = \frac{H_r}{\sqrt{2}} \quad \langle C \rangle_{\max} = \frac{2Q_m}{e\pi u H_r^2} \left(\frac{\sigma_z}{\sigma_y} \right)$$

1. Use left equation to determine σ_z
2. Use Figures 5-10 or 5-11 to get x .
3. Determine σ_y from Figures 5-10 or 5-11.
4. Calculate $\langle C \rangle$ from right equation.

Puff

Equation 5-54

$$\langle C \rangle (x, y, z, t) = \frac{Q_m}{\sqrt{2\pi^{3/2}} \sigma_x \sigma_y \sigma_z} \exp \left[-\frac{1}{2} \left(\frac{y}{\sigma_y} \right)^2 \right] \times \left\{ \exp \left[-\frac{1}{2} \left(\frac{z-H_r}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{z+H_r}{\sigma_z} \right)^2 \right] \right\}$$



u, t not explicit in equation

x is implicit thru dispersion coefficients

Coordinate system moves with puff center at $x=ut$

Assume $\sigma_x = \sigma_y$

Simplified Cases - Puff

Concentration on ground below puff center

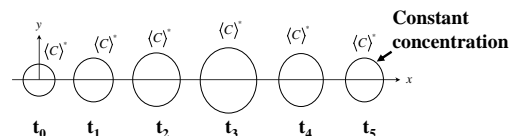
$$\langle C \rangle (0, 0, 0) = \frac{Q_m^*}{\sqrt{2\pi^{3/2}} \sigma_x \sigma_y \sigma_z} \exp \left[-\frac{1}{2} \left(\frac{H_r}{\sigma_z} \right)^2 \right] \quad (5-56)$$

Same as above, with $H_r = 0$. Puff center on ground.

$$\langle C \rangle (0, 0, 0) = \frac{Q_m^*}{\sqrt{2\pi^{3/2}} \sigma_x \sigma_y \sigma_z} \quad (5-41)$$

Puff center always at release height.

Location of Puff

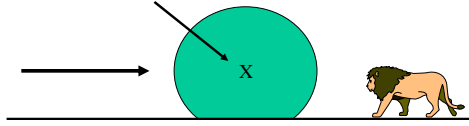


--> Wind = constant at u

Center of puff located at: $x = ut$

Maximum Concentration - Puff

Always at puff center



On ground, max. concentration always occurs directly below puff center.

Example:

10 kg/s of H_2S is released 100 m off of ground. Estimate the concentration 1 km downwind on ground? It is a clear, sunny day, 1 PM, wind speed = 3.5 m/s. Assume rural conditions.

Plume, due to continuous nature of release!

From Table 5-1, Stability Class B.

From Figure 5-10, $\sigma_y = 130$ m

From Figure 5-10, $\sigma_z = 120$ m

Use Equation 5-51 for a plume.

Example: Apply Equation 5-51

Applies to ground concentration directly downwind of release:

$$\langle C \rangle(x, 0, 0) = \frac{Q_m}{\pi \sigma_y \sigma_z u} \exp \left[-\frac{1}{2} \left(\frac{H_r}{\sigma_z} \right)^2 \right]$$

$$\langle C \rangle(x, 0, 0) = \frac{10.0 \text{ kg/s}}{(3.14)(130 \text{ m})(120 \text{ m})(3.5 \text{ m/s})} \times \exp \left[-\frac{1}{2} \left(\frac{100 \text{ m}}{120 \text{ m}} \right)^2 \right]$$

$$\langle C \rangle(x, 0, 0) = 41.2 \times 10^{-6} \text{ kg/m}^3 = 41.2 \text{ mg/m}^3$$

Use Equation 2-7 to get 29.7 ppm. TLV-TWA is 10 ppm.

Example: Where is max. concentration?

Use Equation 5-53:

$$(\sigma_z)_{x, \max} = \frac{H_r}{\sqrt{2}} = \frac{100 \text{ m}}{1.414} = 70.7 \text{ m}$$

Use equation in Table 5-3 to determine downwind distance:

$$\sigma_z = 0.12x$$

$$70.7 \text{ m} = 0.12x$$

$$x = 590 \text{ m}$$

At this location, from Figure 5-10:

$$\sigma_y = 92 \text{ m}$$

Use Equation 5-52 to calculate max. concentration:

$$\langle C \rangle_{\max} = \frac{2Q_m}{e\pi u H_r^2} \left(\frac{\sigma_z}{\sigma_y} \right) = \frac{(2)(100 \text{ kg/s})}{(2.718)(3.14)(3.5 \text{ m/s})(100 \text{ m})^2} \left(\frac{70.7 \text{ m}}{92 \text{ m}} \right)$$

$$\langle C \rangle_{\max} = 5.14 \times 10^{-4} \text{ kg/m}^3 = 514 \text{ mg/m}^3 = 370 \text{ ppm}$$

Example: What is max. discharge to result in 10 ppm?

Maximum will occur at same location: $(\sigma_z)_{x, \max} = \frac{H_r}{\sqrt{2}}$

10 ppm = 13.9 mg/m³ (Equation 2-7)

Substitute into Equation 5-52:

$$\langle C \rangle_{\max} = \frac{2Q_m}{e\pi u H_r^2} \left(\frac{\sigma_z}{\sigma_y} \right)$$

$$13.9 \times 10^{-6} \text{ kg/m}^3 = \frac{2Q_m}{(2.71)(3.14)(3.5 \text{ m/s})(100 \text{ m})^2} \left(\frac{70.71 \text{ m}}{92 \text{ m}} \right)$$

$$Q_m = 2.7 \text{ kg/s} \quad \text{Not very much!}$$

Example:

10 kg of H₂S is released instantly on the ground. What is concentration at fenceline 100 m away? Same conditions as before.

From Table 5-1, stability class is B.

At x = 0.1 km, from Figure 5-12: $\sigma_y = 10$ m $\sigma_z = 16$ m

Use Equation 5-41 for a ground release, centerline conc.:

$$\langle C \rangle (0, 0, 0) = \frac{Q_m}{\sqrt{2\pi^{3/2}} \sigma_x \sigma_y \sigma_z}$$

Assume $\sigma_x = \sigma_y$

$$Q_m = 10 \text{ kg} = 10 \times 10^6 \text{ mg}$$

$$\langle C \rangle = 79.4 \text{ mg/m}^3 = 571 \text{ ppm}$$

Example:

How long does it take for puff to reach fenceline?

$$x = ut$$

$$t = \frac{x}{u} = \frac{100 \text{ m}}{3.5 \text{ m/s}} = 28.6 \text{ s after release.}$$

Very little time for an emergency response!

Example:

What size release will result in 10 ppm at fenceline?

Same procedure as for plume. Answer is 0.175 kg = 175 gm.

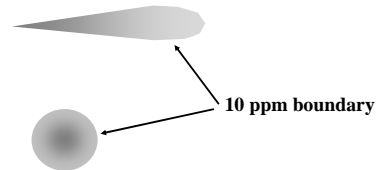
Not very much! Better to contain chemicals than to mitigate after a release!

Isopleths

What: Lines of constant concentration

Plume:

Puff:

**Determining Isopleths: Plume and Puff**

Divide equation for centerline concentration by equation for ground level concentration. Solve for y, which is crosswind direction.

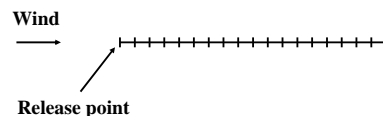
$$y = \sigma_y \sqrt{2 \ln \left(\frac{\langle C \rangle (x, 0, 0, t)}{\langle C \rangle (x, y, 0, t)} \right)} \quad (5-45)$$

Downwind, ground centerline conc.

Isopleth conc.

Procedure to Determine Isopleths - 1

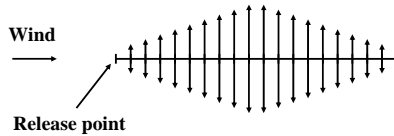
1. Determine concentrations along centerline at fixed points downwind.



2. Use equation (5-45) to find y at each fixed point.

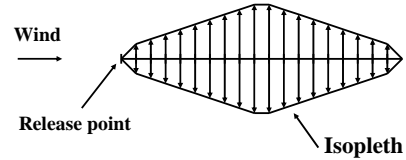
Procedure to Determine Isopleths - 2

3. Plot +y and -y at each fixed point.



Procedure to Determine Isopleths - 3

4. Connect the points.



Worst Case on Ground- Plume and Puff

Want maximum $\langle C \rangle$ downwind

Plume: Centerline, ground, $H_r = 0$ $\langle C \rangle (x, 0, 0) = \frac{Q_m}{\pi \sigma_y \sigma_z u}$

Puff: Center of puff on ground, $H_r = 0$

$$\langle C \rangle (x, 0, 0) = \frac{Q_m^*}{\sqrt{2\pi}^{3/2} \sigma_y \sigma_z u}$$

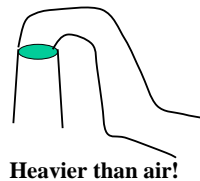
Specify: Q_m and Q_m^* at maximum

σ'_s are minimum \rightarrow F stability

u is minimum within stability class \rightarrow 2 m/s

(EPA suggests 1.5 m/s!)

Dense Gas Dispersion

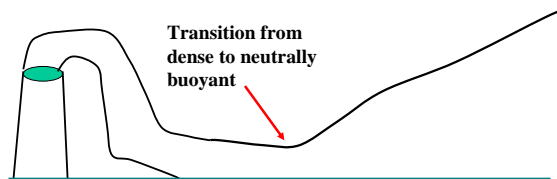


Britter-McQuaid Dense Gas Dispersion Model:

Based on dimensionless groups and available experimental data.

See pages 195-199.

Dense Gas Dispersion



Results in shorter distances if only dense gas.
Results in longer distances if dense gas coupled with Gaussian dispersion.

Toxic Effect Criteria

What concentration should we use for emergency releases?

Cannot use PEL or TWA since these are for continuous work exposures – values are too low for short-term exposures.

ERPGs – Emergency Response Planning Guidelines, issued by American Industrial Hygiene Association

EEGLs – Emergency Response Guidance Levels, issued by National Academy of Sciences/National Research Council.

LOC – Level of Concern from EPA

Toxic Endpoints promulgated by EPA as part of RMP

ERPG: Emergency Response Planning Guideline

ERPG-1: max. airborne concentration below which it is believed nearly all individuals can be exposed for up to 1-hr without experiencing effects other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

ERPG-2: max. airborne conc. below which it is believed nearly all individuals can be exposed up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms that could impair their ability to take protective action.

ERPG: Emergency Response Planning Guideline

ERPG-3: max. airborne concentration below which it is believed nearly all individuals can be exposed for up to 1-hour without experiencing or developing life-threatening health effects.

Table 5-6	ERPG-1	ERPG-2	ERPG-3
Ammonia	25 ppm	200 ppm	1000 ppm
Chlorine	1 ppm	3 ppm	20 ppm
Monomethylamine	10 ppm	100 ppm	500 ppm
Toluene	50 ppm	300 ppm	1000 ppm

EEGL: Emergency Exposure Guidance Levels

A concentration of a gas, vapor, or aerosol that is judged acceptable and allows exposed individuals to perform specific tasks during emergency conditions lasting from 1 to 24 hours.

Table 5-7	1-hr EEGL	24-hr EEGL
Ammonia	100 ppm	
Chlorine	3 ppm	0.5 ppm
Toluene	200 ppm	100 ppm

IDLH: Immediately Dangerous to Life and Health

A concentration that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment.

Available from OSHA (osha.gov) or NIOSH Pocket Guide.

Ammonia	50 ppm
Chlorine	10 ppm
Toluene	500 ppm

LOC: Level of Concern

The max. concentration of an extremely hazardous substance in air that will not cause serious irreversible health effects in the general population when exposed to the substance for relatively short duration.

See EPA for values.

Toxic Endpoints

Must be used for dispersion modeling required for the EPA RMP. Values are, in order of preference, ERPG-2 or LOC.

Ammonia	0.14 mg/L
Chlorine	0.0087 mg/L
Chloroform	0.49 mg/L

Table 5-8

Proposed Hierarchy to Estimate Values

Table 5-9: ORDER IS REVERSED IN TABLE!

<u>Primary</u>	<u>Secondary</u>	<u>Benzene</u>
ERPG-3:	EEGL (30-min)	1000 ppm
	IDLH	500 ppm
ERPG-2:	EEGL (60 min)	150 ppm
	LOC	
	PEL-C	
	TLV-C	
	5 x TLV-TWA	50 ppm

Proposed Hierarchy to Estimate Values (con't)

<u>Primary</u>	<u>Secondary</u>	<u>Benzene</u>
ERPG-1:	PEL-STEL	50 ppm
	TLV-STEL	5 ppm
	3 x TLV-TWA	30 ppm