Dispersion of Air Pollutants into the Atmospheric Air

Pollutant Emission Rate = Q

$\mu g := 10^{-6} \cdot gm$

A. Air Pollutant Concentrations Downwind of Emission Source

$Q := 1 \cdot \frac{gm}{sec}$

Wind Speed = u

1. Flow Box or Pipe Model

$Area := 100 \cdot ft^2$

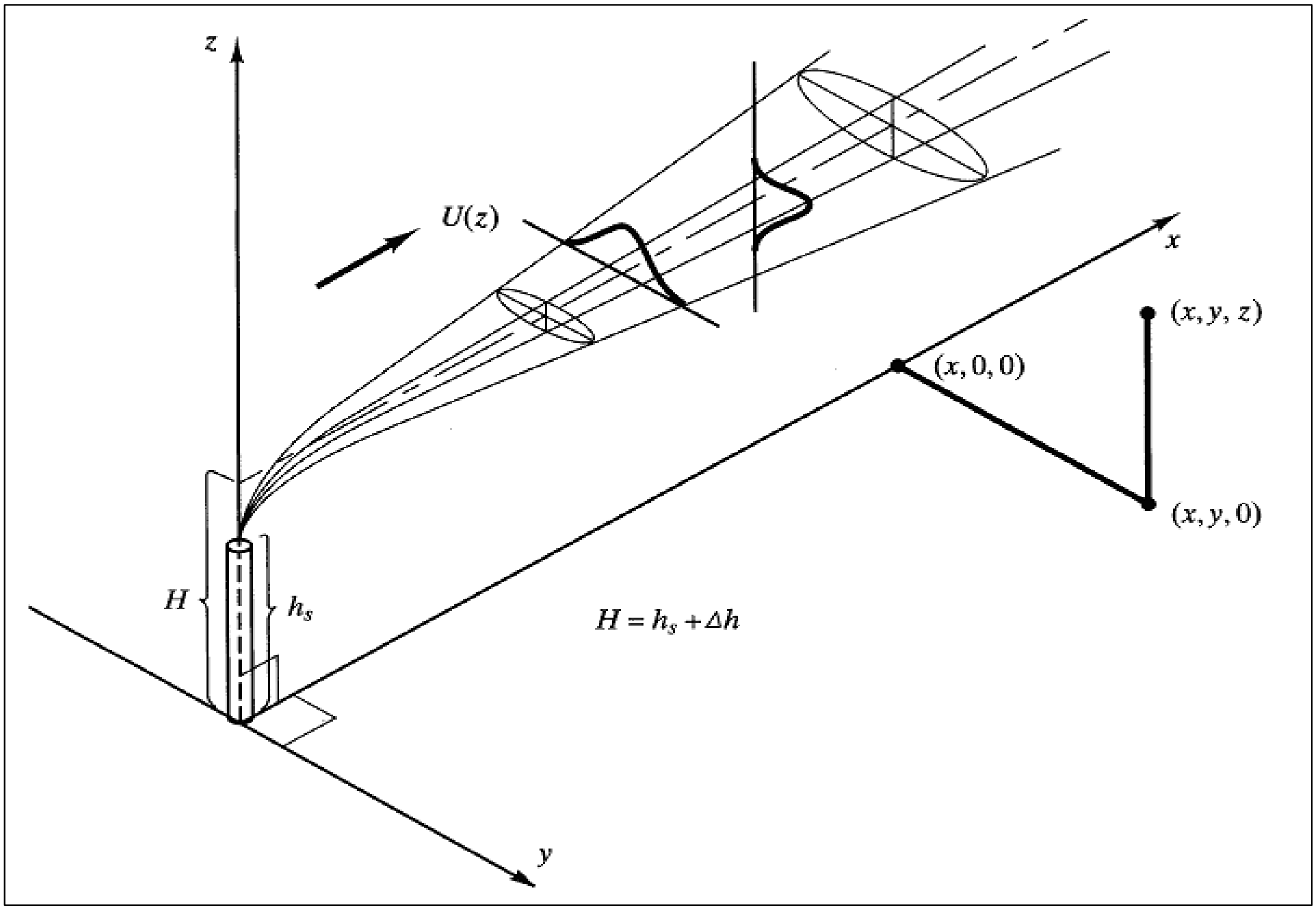
$u := 2 \cdot \frac{m}{sec}$

Area = area perpendicular to wind direction

$Conc := \frac{Q}{u \cdot Area}$

$Conc = 5.382 \times 10^4 \frac{\mu g}{m^3}$

2. Gaussian Disperson Model (basis for EPA models such as SCREEN3, ISC3, etc.



Downwind Distance = x   Crosswind Distance = y
Stack height = h_s Plume Rise = Δh Effective Plume Height = H

Equation for air pollutant conc. at location downwind x, y, z and at effective plume height H and with plume reflection (note that plume reflection is almost always assumed as the amount of air pollutant absorption into the earth's surface is not known)

$$C_{Reflection} := \left(\frac{Q}{2 \cdot \pi \cdot u \cdot \sigma_y \cdot \sigma_y}\right) \cdot exp\left[-\left(\frac{y^2}{2 \cdot \sigma_y^{\,2}}\right)\right] \cdot \left[exp\left[-\left(\frac{z-H}{2 \cdot \sigma_z^{\,2}}\right)\right] + exp\left(\frac{z+H}{2 \cdot \sigma_z^{\,2}}\right)\right]$$

a. Ground Level Air Pollution Conc Downwind of Ground Level Emission Point Source

b. Dispersion Coefficients

x must be in km

$$C_{GroundLevel} := \frac{Q}{\pi \cdot u \cdot \sigma_y \cdot \sigma_z}$$

$$\sigma_y := a \cdot x^{0.894}$$

$$\sigma_z := c \cdot x^d + f$$

x less	1 km					x greater	1 km	
Stability	a	c	d	f		c	d	f
A	213	440.8	1.941	9.27		459.7	2.094	-9.6
B	156	106.6	1.149	3.3		108.2	1.098	2.0
C	104	61.0	0.911	0		61.0	0.911	0
D	68	33.2	0.725	-1.7		44.5	0.516	-13.0
E	50.5	22.8	0.678	-1.3		55.4	0.305	-34.0
F	34	14.35	0.740	-0.35		62.6	0.180	-48.6

b Ground Level Air Pollution Conc. Downwind of Point Emission Source with Plume Rise

Plume Rise = Δh

Example with ground level emission (ie h = 0) with plume rise = 3m such that H = Δh.
x = 100 m, Q = 1 gm/sec, atm stability class C

$$x := 100 \cdot m$$

$$h := 0 \cdot m$$

$$\sigma_y := (104 \cdot m) \cdot \left(\frac{x}{km}\right)^{0.894}$$

$$\sigma_z := (61 \cdot m) \cdot \left(\frac{x}{km}\right)^{0.911} + 0$$

$$\Delta h := 3 \cdot m$$

$$H := h + \Delta h$$

$$\sigma_y = 13.275\,m$$

$$\sigma_z = 7.487\,m$$

$$H = 3\,m$$

Equation for air pollutant concentration below includes reflection of plume from earth's surface

$$C_b := \left(\frac{Q}{\pi \cdot u \cdot \sigma_y \cdot \sigma_z}\right) \cdot \exp\left[-\frac{\left[(H)^2\right]}{2 \cdot (\sigma_z)^2}\right]$$

$$C_b = 1477.73 \frac{\mu g}{m^3}$$

c Ground Level Air Pollution Conc. Downwind of Stack Emission Source with Plume Rise

$$h := 10 \cdot m$$

Example with stack emission (ie h = 10m) with plume rise = 3m such that H = Δh.
x = 100 m, Q = 1 gm/sec, atm stability class C

$$H := h + \Delta h$$

$$H = 13\,m$$

$$C_c := \left(\frac{Q}{\pi \cdot u \cdot \sigma_y \cdot \sigma_z}\right) \cdot \exp\left[-\frac{\left(H^2\right)}{2 \cdot (\sigma_z)^2}\right]$$

$$C_c = 354.69 \frac{\mu g}{m^3}$$

d Ground Level Air Pollution Conc. Downwind of Stack Emission Source with Plume Rise & y = 20 m

$$y := 20 \cdot m$$

$$C_d := \left(\frac{Q}{\pi \cdot u \cdot \sigma_y \cdot \sigma_z}\right) \cdot \left[\exp\left[-\frac{\left(H^2\right)}{2 \cdot (\sigma_z)^2}\right]\right] \cdot \left[\exp\left[-\left[\frac{y^2}{2 \cdot (\sigma_y)^2}\right]\right]\right]$$

$$C_d = 114.015 \frac{\mu g}{m^3}$$

Wark Warner & Davis Prob. 1.1 Carbon Monoxide Concentrations
Given: 1 hr average CO conc of 35ppm at 25°C
Find: Equivalent 1 hr CO conc in milligrams/m³ and micrograms/m³ at 1 atm pressure & 25°C

$MolecularWtCO := 12.011 + 16.000$ $MolecularWtCO = 28.011$ $MWt_{CO} := 28.011 \cdot \frac{gm}{mole}$

$C_{ppm} := 35$ $P := 1 \cdot atm$

Universal Gas Constant = RG

$RG := 0.082054 \cdot \frac{liter \cdot atm}{mole \cdot K}$

$PV := n \cdot R \cdot T$ $T := (460 + 77) \cdot R$ $T = 298.333\,K$ $T = 537\,R$

$C_{CO} := \frac{C_{ppm} \cdot MWt_{CO} \cdot P}{RG \cdot T \cdot 10^{6}}$ $C_{CO} = 4.005 \times 10^{4} \frac{\mu g}{m^{3}}$ $C_{CO} = 40.049 \frac{mg}{m^{3}}$

WW&D Prob 1.2 Sulfur Dioxide Concentrations
Given: Sulfur dioxide concentration of 80 micrograms/m³ @25°C and 1 atm. MWt = 64.06
Find: Equivalent conc in ppm by gaseous volume at 25°C

$MWt_{SO2} := 64.06 \cdot \frac{gm}{mole}$ $C_{SO2} := 80 \cdot \frac{\mu g}{m^{3}}$

$C_{ppmSO2} := \frac{\left(10^{6} RG \cdot T \cdot C_{SO2}\right)}{MWt_{SO2} \cdot P}$ $C_{ppmSO2} = 0.030571$

$Vol := 1 \cdot m^{3}$ $Vol = 35.31467\,ft^{3}$

WW&D Prob 1.3 Particulate Concentrations
Given: Particulate conc. of 150 micrograms/m³ @ 1 atm and 25°C
Find: Equivalent particulate concentration in grains/ft³ @ 1 atm & 25°C.

$grain := \frac{lb}{7000}$

$LB := 1 \cdot lb$ $LB = 453.59237\,gm$

$PartConc := \left(150 \cdot \frac{\mu g}{m^{3}}\right) \cdot \left(\frac{1 \cdot lb}{453.59237 \cdot gm}\right) \cdot \left(\frac{7000 \cdot grain}{lb}\right) \cdot \left(\frac{1 \cdot m^{3}}{35.31467 \cdot ft^{3}}\right)$

$PartConc = 6.555 \times 10^{-5} \frac{grain}{ft^{3}}$