

Example Problem: Air Pollutant Concentration Downwind of Ground Level Point Source

Given: a. $Q = 1 \text{ gm/sec}$ emission rate of H_2S from ground level vent

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

b. wind speed = $u = 3 \text{ meter/sec}$

c. atmospheric stability classes of B and D (or 2 and 4)

d. "Acceptable source impact level" or ASIL for $\text{H}_2\text{S} = 0.9 \mu\text{g/m}^3$ for 24 hr average

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

e. equation 4-10 page 151 WW&Davis, for conc downwind with $Z = 0, Y = 0$

$$u := 3 \cdot \frac{\text{m}}{\text{sec}}$$

where Z is the vertical height above ground level & $Y =$ distance from plume centerline (or in otherwords, equation is for ground level emission & ground level air poll. conc.)

$$i := 0..7$$

Find: H_2S concentration in $x = 100$ to 7000 meters downwind.

The equation for pollutant conc C , eq 4.10 page 151 Wark Warner & Davis is shown below:

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

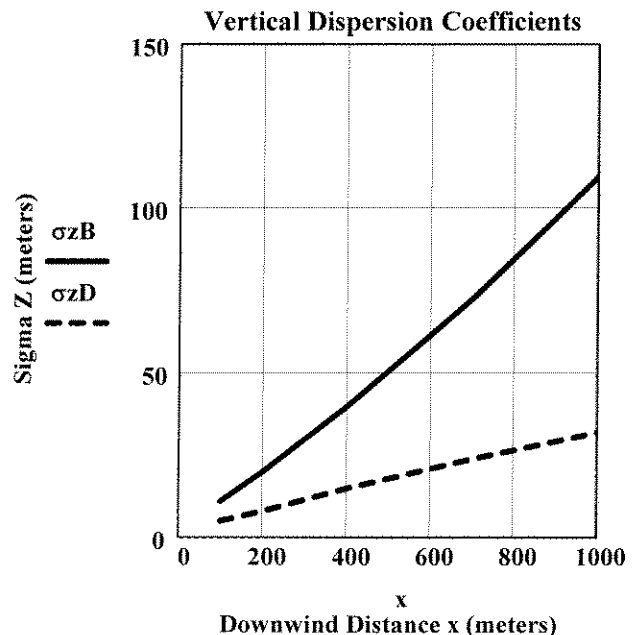
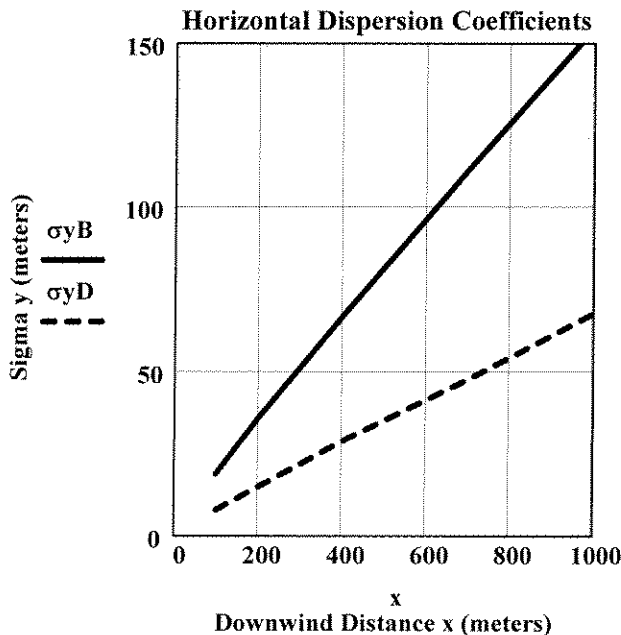
Using 8 downwind distances x meters

x is the downwind distance from the ground vent

The parameters σ_y and σ_z are the horizontal and vertical dispersion coefficients (sometimes called "standard deviations" as is presented on page 152 WW&D). These dispersion coefficients are for 10 minute average air pollutant concentrations, air pollutant concentrations in flat level open country, and for concentrations in under about 200 meters elevation above ground level. σ_y and σ_z are a function of the atmospheric stability class and downwind distance x from the emission. The σ_y and σ_z shown below are from a table in Wark & Warner, 2nd edition.

$$x := \begin{pmatrix} 100 \\ 200 \\ 400 \\ 700 \\ 1000 \\ 2000 \\ 4000 \\ 7000 \end{pmatrix} \cdot \text{m}$$

$$\sigma_{yB} := \begin{pmatrix} 19 \\ 36 \\ 67 \\ 112 \\ 155 \\ 295 \\ 550 \\ 880 \end{pmatrix} \cdot \text{m} \quad \sigma_{zB} := \begin{pmatrix} 11 \\ 20 \\ 40 \\ 73 \\ 110 \\ 230 \\ 500 \\ 780 \end{pmatrix} \cdot \text{m} \quad \sigma_{yD} := \begin{pmatrix} 8 \\ 15 \\ 29 \\ 48 \\ 68 \\ 130 \\ 245 \\ 400 \end{pmatrix} \cdot \text{m} \quad \sigma_{zD} := \begin{pmatrix} 5 \\ 8 \\ 15 \\ 24 \\ 32 \\ 50 \\ 77 \\ 109 \end{pmatrix} \cdot \text{m}$$



Now we can have Mathcad calculate the downwind H₂S 10 min average concentrations C for the atm stability classes B & D at the various downwind distances x

$$CB_i := \frac{(Q)}{\pi \cdot u \cdot \sigma_y B_i \cdot \sigma_z B_i} \quad CD_i := \frac{(Q)}{\pi \cdot u \cdot \sigma_y D_i \cdot \sigma_z D_i}$$

$$CB = \begin{pmatrix} 507.671 \\ 147.366 \\ 39.591 \\ 12.977 \\ 6.223 \\ 1.564 \\ 0.386 \\ 0.155 \end{pmatrix} \frac{\mu\text{g}}{\text{m}^3} \quad x = \begin{pmatrix} 100 \\ 200 \\ 400 \\ 700 \\ 1000 \\ 2000 \\ 4000 \\ 7000 \end{pmatrix} \text{ m} \quad CD = \begin{pmatrix} 2652.582 \\ 884.194 \\ 243.916 \\ 92.104 \\ 48.761 \\ 16.324 \\ 5.624 \\ 2.434 \end{pmatrix} \frac{\mu\text{g}}{\text{m}^3}$$

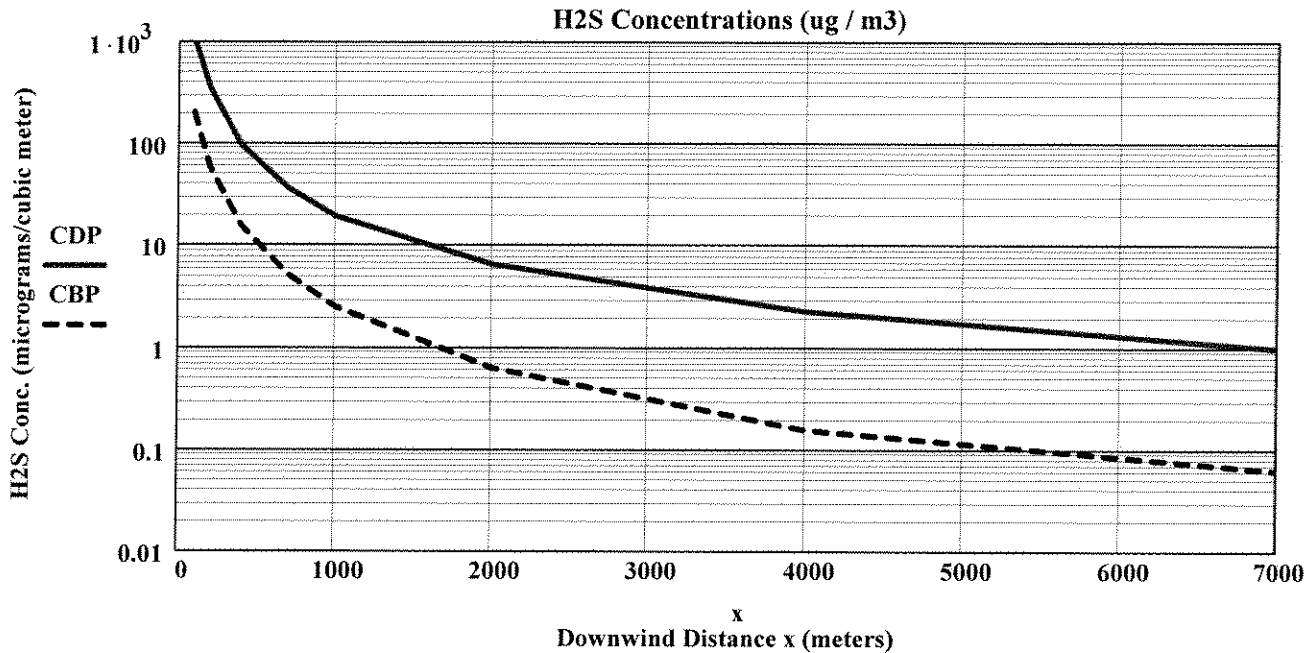
To convert from 10 minute to 24 hr averaging time, note that the EPA assumes the 10 min average conc represents the maximum 1-hr conc. and in the Table on page 169 WW&D it shows the 24 hr average conc. = 0.40 (1 hr average conc)

$$CBP_i := (0.4) \cdot (10^9 \cdot CB_i)$$

For graphing, convert the conc from kg/m³ to microgram/m³ multiply by 10⁹ (Mathcad 7 graphs conc. in kg/m³ and not able to change it to micrograms/m³)

$$CDP_i := (0.4) \cdot (10^9 \cdot CD_i)$$

The graph shows the 24 hr average H₂S concentrations downwind for Atm Stab Classes B & D. The upper solid curve is class D, the dashed curve is B.



Do any of the H₂S concentrations exceed the Washington State ASIL or Accepted Source Impact Level of 0.9 μg/m³ for 24 hr average concentration?

Yes - the 24 hr H₂S concentration exceeds 0.9 μg/m³ for downwind distances from x = 0 to about x = 6500 meters for atmospheric stability class D - and from x = 0 to x = 1700 meters for class B.

The ASIL is the "Accepted Source Impact Level" and is used by the State of Washington. Most other states use the AAL or "Acceptable Ambient Level" for the "standard" for toxic and/or hazardous air pollutants (applies to permit to construct applications).

Example Problem: Reduction in H₂S Conc. Downwind of Emission Source to Meet ASIL

- Given: a. Q = 1 gm/sec H₂S emission rate from ground level vent.
 b. wind speed = u = 3 m/sec
 c. Atmospheric stability classes of B and D
 d. "Acceptable Source Impact Level" = ASIL for H₂S = 0.9 µg/m³ 24 hr average
 e. Ground level H₂S concentrations at downwind distances (from DispersionH2S.mcd).

$$C_{10min} := \frac{Q}{\pi \cdot \sigma_y \cdot \sigma_z \cdot u} \quad C_{24hr} := C_{10min} \cdot \left(\frac{10min}{1440min} \right)^{0.2} \quad \mu g := (10^{-6}) \cdot gm$$

Downwind x	100 meters	200 meters	400 meters	700 meters
C(µg/m ³) for B	507.7	147.37	39.59	12,98
C(µg/m ³) for D	2,652.58	884.19	243.92	92.10

$$ASIL := 0.9 \cdot \frac{\mu g}{m^3}$$

- Find: a. What % Reduction in the downwind ambient H₂S is needed in order to meet the ASIL?
 b. What % Reduction is need in the ground level emission rate so as to meet the ASIL?

Solution

a. What % Reduction in the downwind ambient H₂S is needed in order to meet the ASIL?
 EPA assumes that 10 minute average conc represent maximum 1-hr conc and in the Table on page 169 WW&D, it shows the 24 hr average conc = 0.40(1 hr average conc). Let us convert the 10 minute average H₂S conc at x = 100 yards for class D to the 24 hr average using EPA approach. Note that the EPA software TSCREEN has the option of converting the 1 hr average air pollutant conc to 24 hr and annual average conc.

$$C_{24hr} := \left[2651 \cdot \frac{\mu g}{m^3} \cdot \left(\frac{1 \cdot hr}{24hr} \right)^{0.2} \right] \quad C_{24hr} = 1404.001 \frac{\mu g}{m^3}$$

Thus we need to reduce the 24 hr average concentration of H₂S to the ASIL 24 hr average concentration of 0.9 mg/m³ in order to meet this ASIL Washington State regulation.

$$ReductionNeeded := \left(\frac{C_{24hr} - ASIL}{C_{24hr}} \right) \quad ReductionNeeded = 0.99936$$

H₂S Airborne Concentration Reduction Needed = 99.936%

- b. How can this H₂S downwind conc. at 100 meters downwind be reduced by 99.936%
 Answer: If there is no background upwind H₂S present, then the emission rate needs to be reduced by at least 99.936%. If there is upwind H₂S in the air, this needs to be taken into account.

- c. The emission stack height could be increased from H = 0 to some magnitude and this would decrease the ground level concentrations of downwind H₂S.