Assignment 1

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1) → Determine Stability class:

V_0 = wind speed at ground level = 4 m/s and clear summer day

Stability class = B

$\therefore P = 0.15$

$Q = 80\ g/s$ (given) $H = 200\ m$ (given)

→ Estimate wind speed at effective stack height:

$$\therefore V_z = 4 \times \left(\frac{200}{10}\right)^{0.15} = 5.65\ m/s = u$$

→ determine σ_y and σ_z

downwind distance $(x) = 2\ km$

$\sigma_y = 290\ m$

$\sigma_z = 220\ m$

→ determine concentration:

a) $x = 2000\ m$, $y = 0$ | $C(x,y) = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \exp\left(-\frac{H^2}{2\sigma_z^2}\right)$

conc. at central line —

$$C(x,0) = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left(\frac{-H^2}{2\sigma_z^2}\right)$$

$$\therefore C(2000,0) = \frac{80}{\pi \times 290 \times 220 \times 5.65} \times \exp\left(-\frac{200^2}{2 \times 220^2}\right)$$

$$= 4.67 \times 10^{-5}\ g/m^3 = \boxed{46.7\ \mu g/m^3}$$

b) $x = 2000\ m$, $y = 100\ m$

$$C(2000,100) = \frac{80}{\pi \times 290 \times 220 \times 5.65} \exp\left[-\frac{1}{2}\left(\frac{100}{290}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{200}{220}\right)^2\right]$$

$$= 4.78 \times 10^{-5}\ g/m^3 = \boxed{47.8\ \mu g/m^3}$$

2)

→ Stability class

one hour before sunrise and sky is clear

⇒ Stable condition ⇒ Stability class = F

$Q = 151\ g/s$ $\quad p = 0.3$

$H = 220\ m$ $\quad V_z = 2 \times \left(\frac{220}{10}\right)^{0.3} = 5.06\ m/s$

velocity of wind = 2 m/s at 10 m (assuming)

→ at downwind distance (x) = 2 km

$\sigma_y = 68\ m$ $\quad \sigma_z = 20\ m$

→ conc. at $x = 2000\ m$ $\quad y = 0, z = 0$

$$C(x,0) = \frac{Q}{\pi V_z \sigma_y \sigma_z} e^{-\frac{1}{2}\frac{H^2}{\sigma_z^2}}$$

$$= \frac{151}{\pi \times 5.06 \times 68 \times 20} \exp\left(-\frac{220^2}{2 \times 20^2}\right)$$

$$= \frac{151}{\pi \times 5.06 \times 68 \times 20} \times 5.31 \times 10^{-27} = \boxed{3.71 \times 10^{-29}\ g/m^3}$$

3) $S + O_2 \rightarrow SO_2$

32 64

Sulpher content = $18000 \times \frac{0.58}{100} = 104.4$ ton/day

32 ton S $\rightarrow$ 64 ton SO_2

$\therefore$ 104.4 ton S $\rightarrow 2 \times 104.4 = 208.8$ ton SO_2/

$Q = 208.8$ ton/day $= 2.417$ kg/s

$Q_{SO_2} = 2417$ g/s

$D = 1.5$ $h = 60$m $V_s = 5$ m/s $P = 825$ mbar

$T_a = 28^\circ C = 301K$ $T_s = 155^\circ C = 428K$ $u = 7$ m/s at stack altitude

Stability clan = E

Plume rise $\Delta h_v = \frac{V_s \cdot D}{u}\left[1.5 + 2.68 \times 10^{-3} \times P \times D \times \left(\frac{T_s - T_a}{T_s}\right)\right]$

$\Delta h_v = \frac{5 \times 1.5}{7}\left[1.5 + 2.68 \times 10^{-3} \times 825 \times 1.5 \times \left(\frac{428 - 301}{428}\right)\right]$

$= 2.66$ m

For moderately stable plume $\Rightarrow \Delta h_v = 2.66 \times \frac{90}{100}$

$= 2.394$ m

a) H = Effective stack height $= h + \Delta h_v = 60 + 2.394$

$= 62.39$ m.

b) For stability clan = E

$x = 2000$ m $\sigma_y = 96$m $\sigma_z = 33$m

$\therefore SO_2$ conc. at centreline — $C = \frac{Q}{\pi \times u \times \sigma_y \times \sigma_z} \times e^{-\frac{H^2}{2\sigma_z^2}}$

$\therefore C = \frac{2417}{\pi \times 7 \times 96 \times 33} \times e^{-\left(\frac{62.39^2}{2 \times 33^2}\right)}$

$= 5.81 \times 10^{-3}$ g/m^3

3.c) For max^m ground level conc. (C_{max}) —

$$\sigma_z = 0.707 H = 0.707 \times 62.39 = 44.11 m.$$

For stability class E, $x_{max} \approx 3km = 3000m$.

$\therefore x = 3000m$, $\sigma_y = 150m$.

$$C_{max} = \frac{Q_{SO_2}}{\pi \times \sigma_y \times \sigma_z \times u} \times \exp\left(-\frac{H^2}{2\sigma_z^2}\right)$$

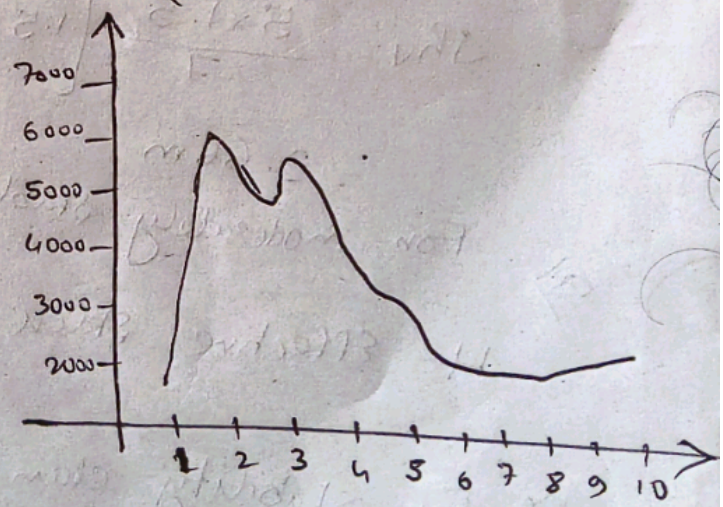
$$= \frac{2417}{3.14 \times 150 \times 44.11 \times 7} \times \exp\left(-\frac{62.39^2}{2 \times 44.11^2}\right)$$

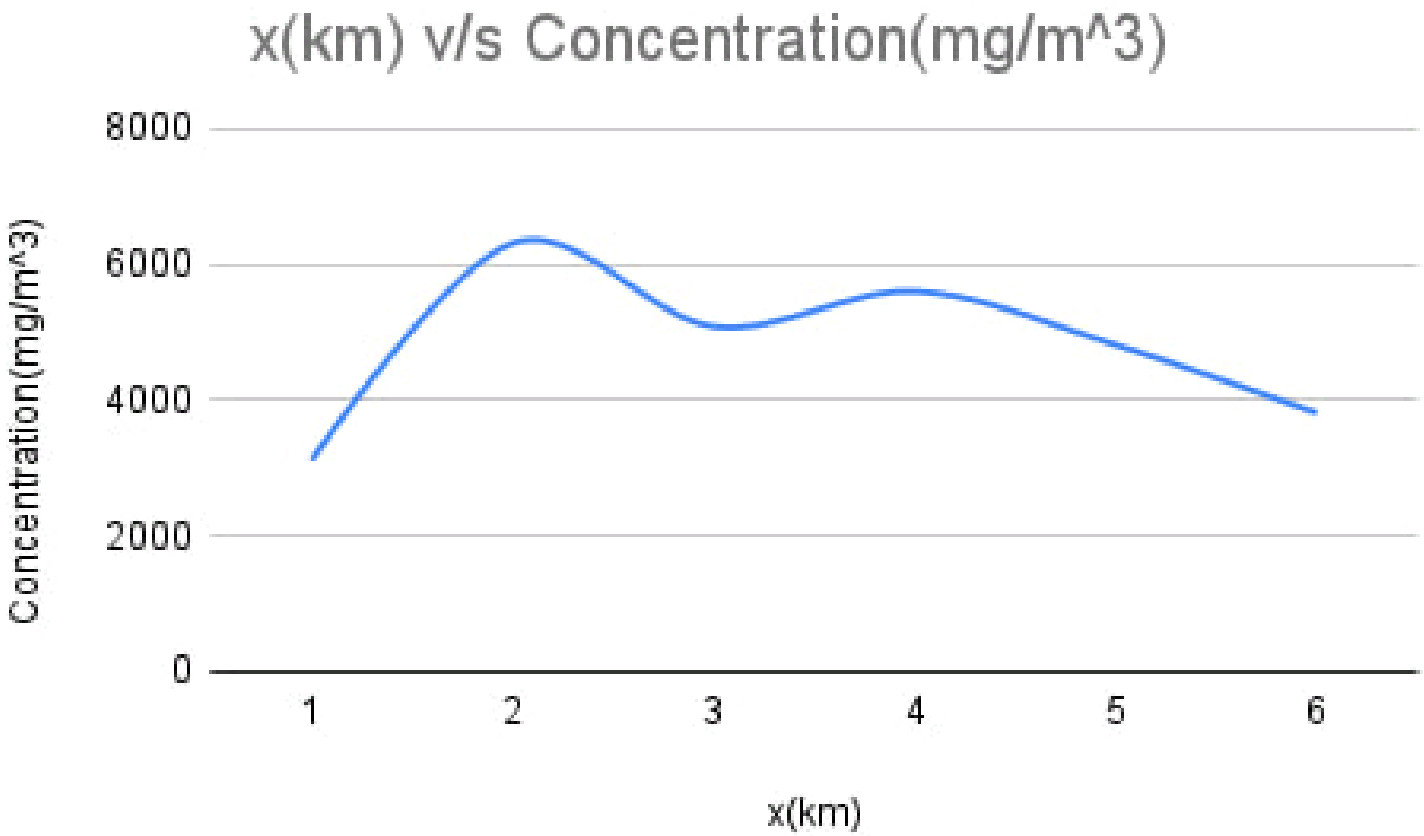
$$C_{max} = 6.11 \times 10^{-3} g/m^3$$

d) SO_2 Profile for SO_2 upto 10km downwind distance —

i) $$C_{x,0} = \frac{2417}{3.14 \times 150 \times \sigma_y \times \sigma_z} \times e^{-\left(\frac{62.39^2}{2\sigma_z^2}\right)}$$

x	σ_y	σ_z	$C_{x,0}$ (mg/m^3)
1	50	24	3117
2	95	34	6314
3	160	40	5085
4	180	50	5604
5	220	57	4813
6	280	60	3808
7	300	65	3554
8	340	70	3103
9	390	75	2657
10	420	80	2413

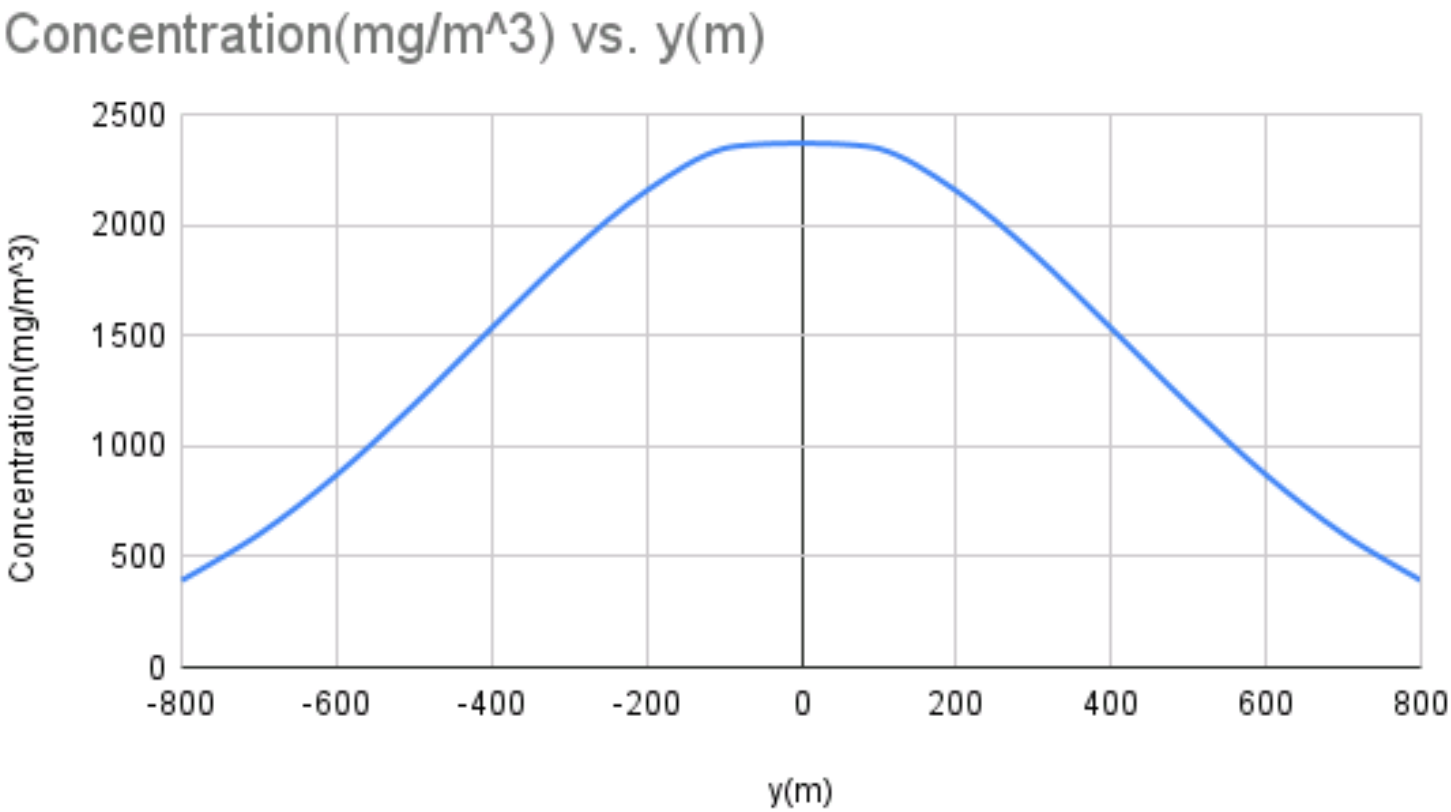



x(km) v/s Concentration(mg/m^3)
8000
6000
4000
2000
0
Concentration(mg/m^3)
1
2
3
4
5
6
x(km)

iv) $y = 800m$ Crosswind dist^n

$$C_{x,0^2} \frac{2417}{\pi \times 7 \times 420 \times 80} \times e^{-\frac{1}{2}\left[\frac{62.4^2}{80^2} + \frac{y^2}{420^2}\right]}$$

y	$C_{x,0}(\mu g/m^3)$
100	2345.35
200	2154.16
300	1869.51
400	1533.05
500	1187.87
600	869.68
700	601.63
800	393.26


Concentration(mg/m^3) vs. y(m)
Concentration(mg/m^3)
2500
2000
1500
1000
500
0
-800
-600
-400
-200
0
200
400
600
800
y(m)

4) $Q = 115\ g/s$ $T_s = 175°C = 448K$ $T_a = 30°C = 303K$

$V_s = 8\ m/s$ $P = 977$ milibars $u_1 = 4\ m/s$ at 10m (anemometer)

Stability class = C $\Rightarrow P = 0.20$ $\Rightarrow u_2 = u_1 \left(\frac{z_2}{z_1}\right)^P$

$D = 96cm = 0.96m$ $= 4 \times \left(\frac{58.32}{10}\right)^{0.2}$

$= 5.69\ m/s$

$h = 74 \times (Q_p)^{0.27}$ | $Q_p = 115\ g/s$

$= 58.32m = z_2$ $= 115 \times 10^{-6} \times 3600$ Tons/hr

a)

$$\Delta h_{v_s} = \frac{V_s D}{u_2}\left[1.5 + 2.68 \times 10^{-3} \times P \times D \times \left(\frac{T_s - T_a}{T_s}\right)\right]$$

$$= \frac{8 \times 0.96}{5.69}\left[1.5 + 2.68 \times 10^{-3} \times 977 \times 0.69 \times \left(\frac{448 - 303}{448}\right)\right]$$

$= 3.12m$

for slightly unstable plume $\Delta h_{v_s} = 1.1 \times 3.12 = 3.43m$

$\therefore H_{eff} = h + \Delta h_{v_s} = 58.32 + 3.43 = 61.75m$

b) Conc. of dust at 6km downwind along central line of plume — $x = 6000\ m \Rightarrow \sigma_y = 560\ m$ $\sigma_z = 310m$.

$$\therefore C_{x,0} = \frac{Q}{\Pi \times u_2 \times \sigma_y \times \sigma_z} e^{-\frac{H^2}{2\sigma_z^2}}$$

$$= \frac{115}{\Pi \times 5.69 \times 560 \times 310} \times e^{-\frac{61.75^2}{2 \times 310^2}} = 3.63 \times 10^{-5}\ g/m^3$$

4.c) $\sigma_z(x_{max}) = 0.707 H_{eff} = \cancel{0.707} \times$

$= 0.707 \times \cancel{61.44}\ 61.75 = 43.65\ m$

$\therefore x_{max} \approx 0.\cancel{7}75\ km = \cancel{7}50\ m$

$\therefore \sigma_y(x_{max}) = 85\ m.$

$$\therefore C_{max} = \frac{Q}{\pi \sigma_y(x_{max}) \sigma_z(x_{max}) \times u_2} \times \exp\left(-\frac{H_{eff}^2}{2 \times \sigma_z(x_{max})^2}\right)$$

$$= \frac{115}{\pi \times 85 \times 43.65 \times 5.69} \times \exp\left(-\frac{61.75^2}{2 \times 43.65^2}\right)$$

$$= \boxed{6.37 \times 10^{-4}\ g/m^3}$$

5) Sulpher content = $240000 ton/day \times \frac{1.7}{100} = 408\ ton/day = \cancel{0}4.72 kg/s$

z_2: $h = 200ft = 60.96m$ $T_s = 140°C = 413K$ $u_1 = 4.5 m/s$ | $z_1 = 10m$ (assume)

$D = 0.8m$ $T_a = 28°C = 301K$ condition = moderately unstable

$v_s = 18.3 m/s$ $P = 1000 mbar$ = class C | $P = 0.2$

$$u_2 = \cancel{200} 4.5 \times \left(\frac{60.96}{10}\right)^{0.2}$$

$= 6.45 m/s$

a) $$\Delta h_v = \frac{v_s \cdot D}{u_2} \times \left[1.5 + 2.68 \times 10^{-3} \times P \times D \times \left(\frac{T_s - T_a}{T_s}\right)\right]$$

$$\Delta h_v = \frac{18.3 \times 0.8}{6.45} \times \left[1.5 + 2.68 \times 10^{-3} \times 1000 \times 0.8 \times \left(\frac{413 - 301}{413}\right)\right]$$

$= 4.71 m \Rightarrow$ for unstable plume $\Rightarrow \Delta h_v = 4.71 \times 1.1 = 5.2 m$

$H = h + 4.71 = 60.96 + \cancel{4.71}\ 5.2 = \boxed{66.14 m.}$

b)

b) $S + O_2 \rightarrow SO_2$

16g 32g

$\therefore SO_2$ content $= 4.72 \times 10^3 \times 2$

$= 9440\ g/s = Q_{SO_2}$

for max^m Ground level conc. at centreline —

$\sigma_z(x_{max}) = 0.707 \times H = 0.707 \times \frac{66.14}{\cancel{65.68}} = 46.76\ m.$

$\therefore x_{max} = 770\ m.$

$\therefore \sigma_y(x_{max}) = 88\ m.$

$$\therefore C_{max} = \frac{Q_{SO_2}}{\pi \times u_2 \times \sigma_y \times \sigma_z} \times \exp\left(-\frac{H^2}{2\sigma_z^2}\right)$$

$$= \frac{9440}{\pi \times 6.45 \times 88 \times 46.76} \times \exp\left(-\frac{\cancel{65.68}^{66.14^2}}{2 \times 46.44^2}\right)$$

$$\approx \boxed{0.038\ g/m^3}$$

c) conc. at $x = 5km$

at $x = 5000m$ $\sigma_y = 470m$ $\sigma_z = 280m.$

$$C_x = \frac{9440}{\pi \times 470 \times 280 \times 6.45} \times \exp\left(-\frac{65.\cancel{68}^{2}}{2 \times 280^2}\right)$$

$$\approx \boxed{3.46 \times 10^{-3}\ g/m^3}$$

Conc. of SO_2 at

$$C_{x,0,0,H_2} = \frac{Q}{\pi u}$$

5c)

for concentration Profile ——

x (km)	σ_y (m)	σ_z (m)	C ($\mu g/m^3$)
0.2	25	15	0.07~~45~~
0.3	35	20	2.80
0.4	50	25	11.26
0.5	60	30	22.79
0.6	70	38	38.53
0.7	80	45	43.96
0.8	90	50	43.18
0.9	100	55	41.12
1	120	60	35.26
2	~~300~~ 200	120	16.68
3	300	180	8.06

at $x = 5$ km

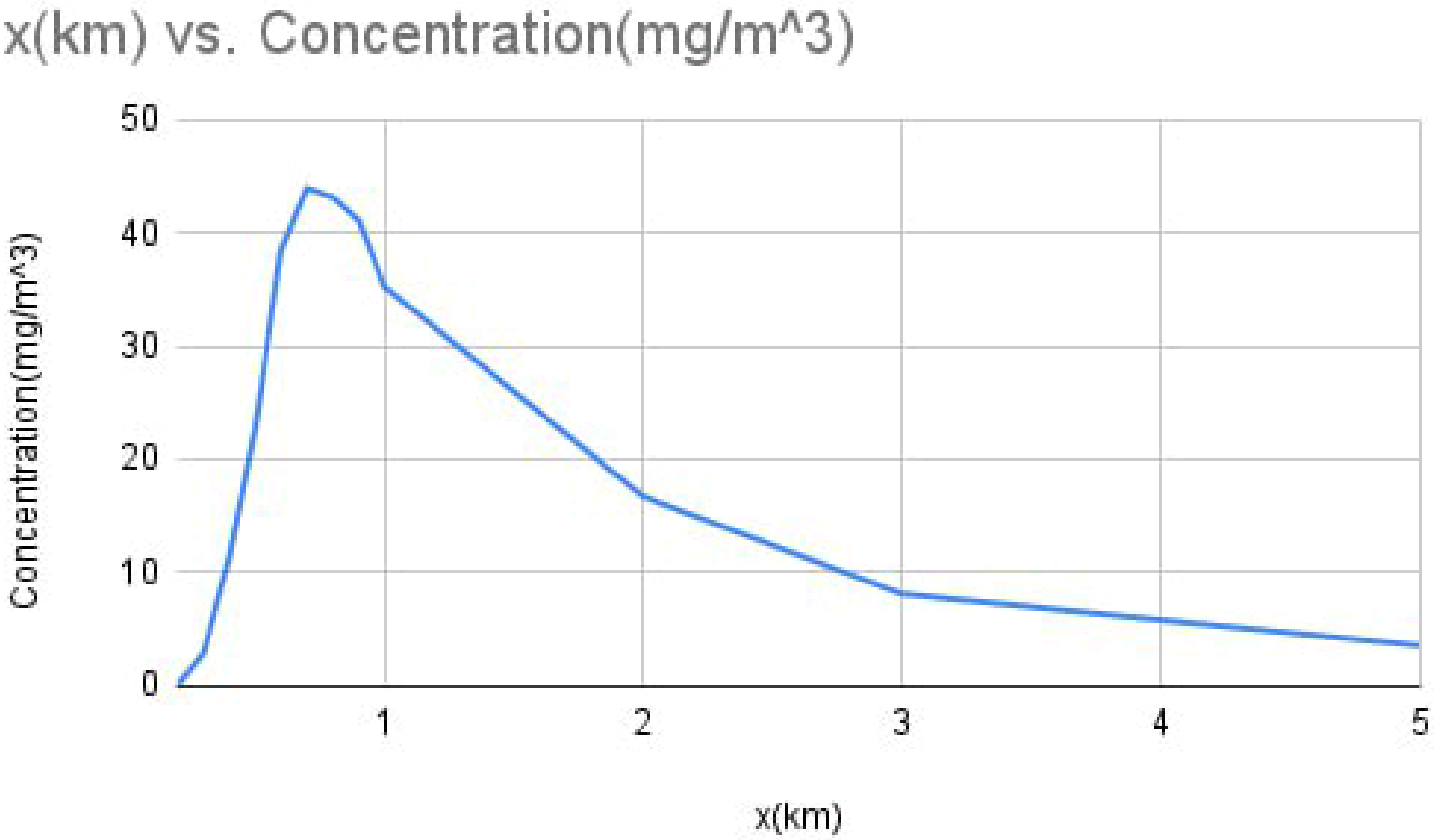
Stability class = C

$\sigma_z = 270$ m

$\sigma_y = 480$ m

$$C_x = \frac{9440}{\pi \times 6.45 \times 480 \times 270} \times \exp\left(-\frac{66.14^2}{2 \times 270^2}\right)$$

$= 3.49 \times 10^{-3}$ g/m^3


x(km) vs. Concentration(mg/m^3)
Concentration(mg/m^3)
50
40
30
20
10
0
1
2
3
4
5
x(km)

6) $h_2 = 200m = z_2$ class = D $\Rightarrow$ P = 0.25

$D = 0.5m$. $P = 100 mBar$

$V_s = 10 m/s$ $T_a = 15^\circ C = 288 K$

$T_s = 120^\circ C = 393 K$ $u_1 = 6 m/s$ $z_1 = 10m$ (assume)

$$u_2 = \left(\frac{200}{10}\right)^{0.25} = 2.11 \text{ m/s}$$

$$\Delta h_v = \frac{V_s D}{u_2}\left(1.5 + 2.68 \times 10^{-3} \times P \times D \times \left(\frac{T_s - T_a}{T_s}\right)\right)$$

$$= \frac{10 \times 0.5}{2.11} \times \left[1.5 + 2.68 \times 10^{-3} \times 100 \times 0.5 \times \left(\frac{393 - 288}{393}\right)\right]$$

$$= 3.64 \text{ m}$$

$$H = h + \Delta h_v = 203.64 m$$

Now, S content = $1000 \times \frac{1.5}{100} = 150$ ton/day $= 1.74$ kg/sec.

$= 1740$ g/sec.

$\therefore SO_2$ emission rate $= 2 \times 1740 = 3480$ g/sec. $= Q_{SO_2}$

$\therefore$ Conc. of SO_2 in the plume central line at distance 5km —

$x = 5000m$ $\sigma_y = 290 m$ $\sigma_z = 90m$

$$C_x = \frac{Q}{\pi u_2 \sigma_y \sigma_z} \times \exp\left(-\frac{H^2}{2 \times \sigma_z^2}\right) = \frac{3480}{\pi \times 2.11 \times 290 \times 90} \times \exp\left(-\frac{203.64^2}{2 \times 90^2}\right)$$

$$= 1.56 \times 10^{-3} \text{ g/m}^3$$

7) $h = 50m$ $P = 100mbar$ $Q = 200g/s$

$d = 2m$ $T_a = 25^\circ C = 298K$ | Stability class = D

$T_s = 120^\circ C = 393K$ | at $x = 1000m$.

$v_s = 10m/s$ $\sigma_y = 70m$

$\sigma_z = 32m$.

$$\Delta h_v = \frac{v_s d}{u}\left[1.5 + 2.68\times10^{-3} P.d \times \left(\frac{T_s - T_a}{T_s}\right)\right]$$

$$= \frac{10\times2}{u}\left[1.5 + 2.68\times10^{-3}\times100\times2\times\left(\frac{393-298}{393}\right)\right]$$

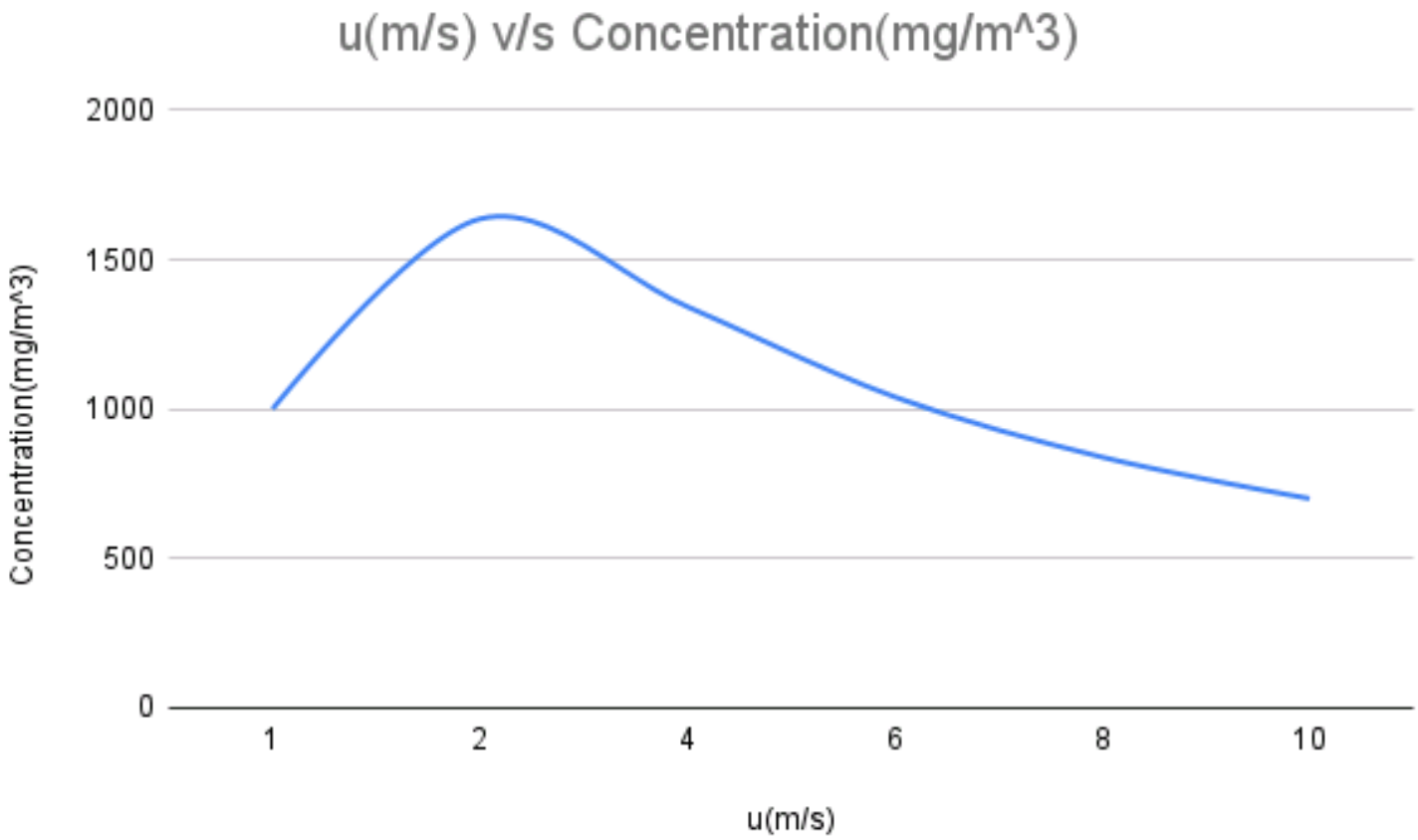
$$= \frac{32.6}{u}$$

$$\therefore H = 50 + \frac{32.6}{u}$$

$$C_{x,0} = \frac{Q}{\pi\times u\times\sigma_y\times\sigma_z} e^{-\left(\frac{H^2}{2\sigma_z^2}\right)} = \frac{200}{\pi\times u\times70\times32} \times e^{-\left(\frac{\left(50+\frac{32.6}{u}\right)^2}{2\times32^2}\right)}$$

$$= \frac{0.028}{u} \times e^{-\left(\frac{\left(50+\frac{32.6}{u}\right)^2}{2048}\right)}$$

Wind Speed u	Effective height H	Concentration $C_{x,0}$ ($\mu g/m^3$)
1	82.6	1000.8
2	66.3	1636.76
4	58.15	1342.89
6	55.43	1040.83
8	54.07	839.43
10	53.26	700.8


u(m/s) v/s Concentration(mg/m^3)
2000
1500
1000
500
0
Concentration(mg/m^3)
1
2
4
6
8
10
u(m/s)

8) $Q = 100\ kg/s = 100 \times 10^3\ g/s$ | $C = 80 \times 10^{-6}\ g/m^3$ at $x = 500\ m$.

a) $u = 7.5\ m/s$ $\quad \sigma_y = 35m$ $\quad \sigma_z = 20m$

$$C(x,0) = \frac{Q}{\pi \times u \times \sigma_y \times \sigma_z} \times e^{-\left(\frac{H^2}{2\sigma_z^2}\right)}$$

$$\Rightarrow \frac{C \times \pi \times u \times \sigma_y \times \sigma_z}{Q} = e^{-\frac{H^2}{2\sigma_z^2}}$$

$$\Rightarrow \ln\left(\frac{C \times \pi \times u \times \sigma_y \times \sigma_z}{Q}\right) = -\frac{H^2}{2\sigma_z^2}$$

$$\Rightarrow -H^2 = -11.24 \times 2 \times \sigma_z^2 \Rightarrow \boxed{H = 94.8m}$$

b) $Q_p = Q = 3 \times 10^{-3}\ ton/hr = 2721.55\ g/hr = 0.83\ g/s$

$$\ln\left(\frac{80 \times 10^{-6} \times \pi \times 7.5 \times 35 \times 20}{0.83}\right) = -\frac{H^2}{2 \times 20^2}$$

$$\Rightarrow H^2 = -2 \times 20^2 \times 0.45902 = -367.22$$

since H^2 is -ve, means low emmission rate, ground level conc. will not exceed the norm even at ground level.

$h = 74 (Q_p)^{0.27}$ | Q_p = Particulate emission rate (Ton/hr)

$h = 74 \times (3 \times 10^{-3})^{0.27} = 15.42m.$

min^m stack height = $\boxed{15.42m.}$