 Chia Peiwen

1a) PSI = 267

$$I = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_p - BP_{Lo}) + I_{Lo}$$

$$267 = \frac{300 - 200}{250 - 150} (C_p - 150) + 200.$$

$$C_p = 217 \ \mu g/m^3$$

$$PM_{2.5} = 622 (VR)^{-0.98}$$

$$217 = 622 (VR)^{-0.98}$$

$$VR = 2.9286 \ km$$

$$b_{ext} = 3.9 \div (2.9286 \times 10^{-3})$$

$$= 1331.7 \ Mm^{-1}$$

b) The nose is unable to effectively filter out particle matter the size of 2.5um. Hence a significant fraction of PM2.5 is deposited in the lungs instead of the nose, which will cause significant respiratory issues. Children and the elderly are more susceptible to respiratory problems and hence are at greater risk of health concern from PM2.5.

c) i) $V = 800 m^3$ $C_o = 5 \mu g/m^3$ $k = 0.6/mth = 8.33 \times 10^{-4}/h.$

$$F_{EM} = 50 \times 2/h \times 25mg$$

$$= 2500 \ mg/h$$

$$C_i = \frac{F_{EM} + C_o I V}{(I + k) V}$$

$$35 \mu g/m^3 = \frac{2500 \times 10^3 + 5 \times I \times 800}{(I + 8.33 \times 10^{-4}) \times 800}$$

$$I = 104.2/hr$$

ii) Duration for PM to reach 75% of steady state:

$$e^{-(I+k)t} = e^{-0.75}$$

$$t = \frac{0.75}{(104.2 + 8.33 \times 10^{-4})}$$

$$= 0.43 \ mins$$

2a) Wind speed : 2m/s → weaker mixing in air, more stable

Exposure height : 2m → wind velocity lower near the ground.

Effective Stack height : 10m → lower mixing height.

Stability class : F → stable atmosphere, weak mixing.

b) $Q = 75 mg/s$ $u = 2m/s$, $H = 10m$ $z = 2m$ Stability class : F $x = 300m$

$\sigma_y = 0.067(300)^{0.90} = 11.36$ $\sigma_z = 0.057(300)^{0.80} = 5.46$

Assume reflection on the ground.

$$C_{(x,y,z,H)} = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\}$$

$$= \frac{75}{2\pi \times 11.36 \times 5.46 \times 2}\left\{\exp\left[-\frac{1}{2}\left(\frac{2-10}{5.46}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2+10}{5.46}\right)^2\right]\right\}$$

$$= 41.49 \mu g/m^3$$

conc $PM_{2.5} = 0.8 \times 41.49 \mu g/m^3$

$= 33.19 \mu g/m^3 > 25 \mu g/m^3$ (higher than NEA ambient air quality)

conc $PM_{10} = 0.2 \times 41.49 \mu g/m^3$

$= 8.30 \mu g/m^3$

c) Assumptions:

1. Conservative pollutant : no loss due to chemical decay and reactions
2. Homogenous turbulence (mixing)
3. constant rate of emission, Q

3a) Mass of sulfur $= 5\times10^5$ kg/hr $\times 2.5\%$

$= 12500$ kg/hr

mass rate of SO_2 $= \frac{12500\times10^3}{32} \times 64$ $\qquad \frac{mass}{M.W} = mol$

$= 2.5\times10^7$ g/hr

Mass of $CaCO_3$ needed $= \frac{2.5\times10^7 \times 0.95}{64} \times 100$

$= 3.711\times10^7$ g/hr

$= 3.711\times10^4$ kg/hr

Excess $= 3.92\times10^4 - 3.711\times10^4$

$= 2.09\times10^3$ kg/hr

b) 3 Alternatives:

1. Lime Wet Scrubbing : $Ca(OH)_2$ is more chemically reactive than limestone.
2. Dual Alkali Processes : Na_2CO_3 is soluble in water, soluble deposits are formed in Scrubber.
3. Lime-Spray Drying : No corrosion and scaling, no waste product.

4a) Large : 20% , Medium : 70% , Small : 10%

Let initial mass of all particles be m

After cyclone #1 & #2

Penetration.

$L : \left[\frac{1}{3}(0.1) + \frac{2}{3}(0.05)\right] \times 0.2m = 0.0133m$

$M : \left[\frac{1}{3}(0.35) + \frac{2}{3}(0.25)\right] \times 0.7m = 0.2833m$

$S : \left[\frac{1}{3}(0.8) + \frac{2}{3}(0.6)\right] \times 0.1m = 0.0667m$

Sum $= 0.3633m$

$\therefore$ overall removal efficiency of 2 cyclones $= \frac{m - 0.3633m}{m} = 63.67\%$

New mass before ESP = 0.3633m

New mass after ESP = 0.3633m × $\underbrace{(1-0.76)}_{\text{penetration}}$

= 0.0872m

Let Large, Medium, Small ESP removal efficiency be x, y, z respectively.

x: $0.0133m \times (1-x) = 0.0872m(0.002)$

$x = 0.9868 = 99\%$

y: $0.2833m \times (1-y) = 0.0872m(0.595)$

$y = 0.8168 = 82\%$

z: $0.0667m(1-z) = 0.0872m(0.403)$

$z = 0.4731 = 47\%$

b) Area of 5 Compartments: $112 \times 5 \times 4\,m^2 = 2240\,m^2$

$Q = 2400\,m^3/min$.

$V_s = \frac{Q}{A}$

$m = \mu \cdot C \cdot Q \cdot t$

$V_s = \frac{-\Delta P}{\mu \times \Delta x / k}$

$\Delta x = \frac{m}{\rho A}$

$$\Delta x = \frac{0.99 \times 30\,g/m^3 \times 2400\,m^3/min \times 60\,min}{0.5 \times 2000\,kg/m^3 \times 1000 \times 2240\,m^2}$$

$= 0.0017357\,m$

Solve for K:

$$\frac{2400\,m^3/min \div 60}{2240\,m^2} = \frac{-750\,kg/(m \cdot s^2)}{1.8 \times 10^{-5}\,kg/m \cdot s \times \frac{0.0017357m}{K}}$$

$\therefore K = 8.21 \times 10^{-13}\,m^2$