AY 2022-2023 S2 EN3004 - Air Pollution Control Engineering

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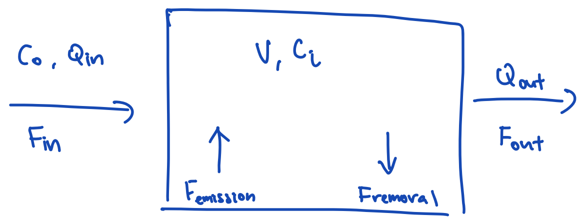
1a) Temp = 23°C , $P = 0.75$ atm.




$I = 570 \text{l}/\text{person} \cdot \text{min}$

b) $C_o = 400 \text{ ppm} = 542.5 \text{ mg}/\text{m}^3 = 0.5425 \text{ g}/\text{m}^3$ , $K = 0.025/\text{yr} = 1.585 \times 10^{-9}/\text{min}$ $I = 18/\text{h} = 0.3/\text{min}$

$F_{EM} = 0.66 \text{g}/\text{person} \cdot \text{min}$

$Q = VI$

$0.570 \text{ m}^3/\text{person} \cdot \text{min} = V \times 0.3/\text{min}.$

$V = 0.570 \div 0.3$

$= 1.9 \text{ m}^3/\text{person}.$

Steady State $C_i = \dfrac{F_{EM} + C_o I V}{(I + K)V}$

$= \dfrac{0.66 + 0.5425 \times 0.3 \times 1.9}{(0.3 + 1.585 \times 10^{-9}/\text{min}) \times 1.9}$

$= 1.70 \text{g}/\text{m}^3$

Assuming that there are 200 passengers on the plane, volume of aeroplane $= 200 \times 1.9 = 380 \text{m}^3 \approx 400 \text{m}^3$

c) CO2 is a greenhouse gas (GHG). These GHGs can absorb appreciable amounts of IR radiation and hence trap heat in the atmosphere. With elevated levels of CO2 in the atmosphere, more radiation and heat is trapped in the atmosphere, resulting in increased temperature and global warming.

d) Mitigation methods limit future effects of anthropogenic climate change while adaption methods deal with the effect of global warming.

Mitigation:

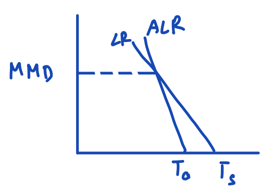
- $CO_2$ capture and storage
- Renewable energy

Adaption:

- Diversifying crops so that they are better able to adapt to changing climates
- Climate-resilient infrastructure

2a) Mixing height sets the upper limit to dispersion of atmospheric pollutants where vigorous vertical mixing from the ground to the mixing height and negligible vertical mixing above the height.

$$\frac{dT}{dZ} = \frac{23-24}{150} = \frac{-1^\circ C}{150\,m} = \frac{-0.67^\circ C}{100\,m} \quad (\text{Stability class D})$$




$T_a = 24^\circ C \quad T_s = 32^\circ C$

To find MMD : TALR = TLR

$$\left(\frac{-1^\circ C}{100}\right)(z) + 32 = \left(-\frac{0.67^\circ C}{100\,m}\right)(z) + 24$$

$$z = 2424\,m$$

bi) $H = 0$, $Q = 1.2\,g/s$, $z = 0\,m$ ($H = 0\,m$), $x = 500\,m$, $u = 4\,m/s$ Stability class : C

$\sigma_y = 0.128(500)^{0.9} = 34.4$ $\quad \sigma_z = 0.093(500)^{0.85} = 18.3\,m$

No ground reflection:

$$C_{(x,y,z)} = \frac{Q}{2\pi \sigma_y \sigma_z u} \cancelto{0}{\exp\left(\frac{-y^2}{2\sigma_y^2}\right)} \left[\exp \frac{-(z-H)^2}{2\sigma_z^2}\right]$$

$$= \frac{1.2}{2\pi \times 34.4 \times 18.3 \times 4}\left[\exp 0\right] = 75.8\,\mu g/m^3$$

2bii) 0.5 ppb = $5\times10^{-4}$ ppm

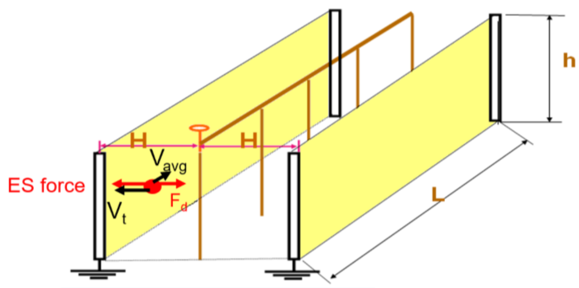
$= 0.6963\ \mu g/m^3$

∴ As calculated in (bi), concentration of $H_2S$ at ground level is much larger than the $H_2S$ concentration threshold of 0.5ppb.

c) 1. Emission rates

2. Stability.

3a)




Dirty air flows into the ESP at velocity Vavg and is ionised, which charges particles into negative charges. Negatively charged particles driven to the positively charged plates by electrostatic force Fd at terminal velocity Vt and attached onto the plates. These particles are then removed, and clean air is passed out.

b) 450 cloth bags $C_o = 20\,g/m^3$ $Q = 50\,m^3/s$

$$\eta = \frac{20 - (50\times10^{-3})}{20} = 99.75\%$$

50 cloth bags → 50% reduction in efficiency = 49.875%

For 50 cloth bags:

Penetration = $20\,g/m^3 \times (1 - 0.49875)$

$= 10.025\,g/m^3$

∴ New concentration = $\frac{50}{450}(10.025) + \frac{400}{450}(50\times10^{-3})$

$= 1.16\ g/m^3$ > regulatory limit of $0.07\,g/m^3$ → Does not meet regulatory limit.

b) To meet limit of $0.07\ g/m^3$

$$\text{efficiency } \eta = \frac{1.16 - 0.07}{1.16}$$
$$= 93.96\ \%$$

4a) In the troposphere, Ozone is formed by a chemical reation between $NO_x$ and $VOC_s$ in the presence of heat and sunlight.

$O_3$ formation: $VOC + NO_x + heat + Sunlight\ (UV) \rightarrow O_3$

At troposphere level, O3 contributes to smog formation, and cause health and environmental effects like air pollution.

At stratosphere level, O3 helps to shield from UV radiation which can cause health issues like skin cancer and eye cataracts. Hence, it is beneficial.

b) Three types of working losses:

- Displacement losses: During filling, liquid enter the tank and displace vapour from the tank's headspace, which is connected by a vent to the atmosphere.
- Emptying losses: When liquid is withdrawn from the tank, air will flow in through the vent to fill the space due to the drop in liquid level.
- Breathing losses: When the tank's temperature changes, there is thermal expansion and contraction of the vapour and liquid in the tank, which causes the vapour to exit, and the surrounding air to enter to fill the space of the vapour.

c) Let $x$ be the total emission of $NO_x$ per minute in grams. (Assuming no stoichiometric excess)

For NO: mass of $NH_3$ needed: $\frac{0.75x}{14+16} \times (14+3) = 0.425x$

For $NO_2$: mass of $NH_3$ needed: $\frac{0.25x}{14+16+16} \times 2 \times (14+3) = 0.185x$

$$0.425x + 0.185x = 10 \times 10^3 g$$

$\therefore x = 16.4\ kg$ Total emission of $NO_x = 16.4 kg/min$.

d)

Emission source: Motor vehicles are the primary emission source of NOx but only contributes a minor portion to SO2 emissions.

Emission control: If sulfur is removed in the fuel, the SO2 emissions can be effectively eliminated, but removing nitrogen from the fuel would only remove about 10-20% of NOx emissions. NOx emissions can be reduced by changing the combustion conditions (time, temperature, and oxygen content), but this is not the case for SO2 emissions.