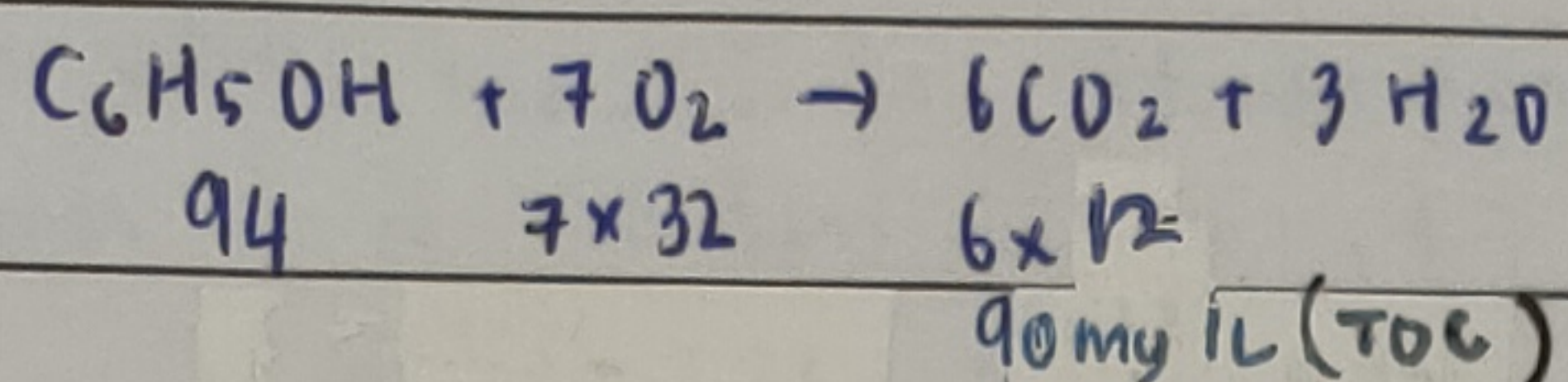


1)

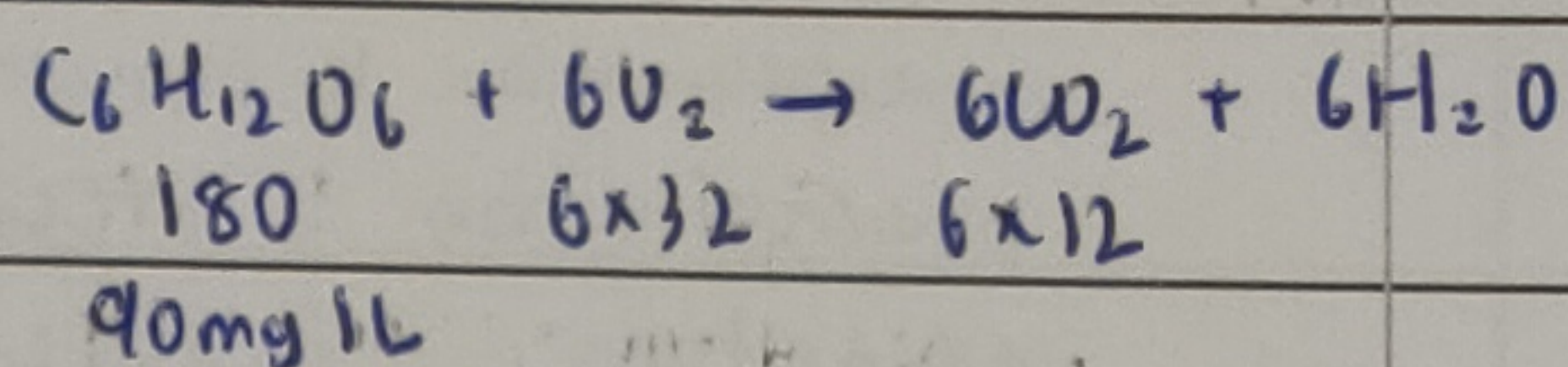
a) Wastewater A:



$$\frac{94}{6 \times 12} \times 90 = 117.5 \text{ mg/L } (C_6H_5OH)$$

$$\frac{7 \times 32}{6 \times 12} \times 90 = 280 \text{ mg/L } (O_2)$$

Wastewater B:



$$\frac{6 \times 32}{180} \times 90 = 96 \text{ mg/L } (O_2)$$

$$\frac{6 \times 12}{180} \times 90 = 36 \text{ mg/L}$$

$$BOD/COD = 0.5$$

$$BOD = COD \times 0.5 = 96 \times 0.5 = 48 \text{ mg/L}$$

In mixed WW,

$$COD = (280 \times 1) + (96 \times 4) = 664 \text{ mg/L}$$

$$BOD = (28 \times 1) + (48 \times 4) = 220 \text{ mg/L}$$

$$BOD/COD = 0.33$$

$$\text{Total flow} = 100 + 400 = 500 \text{ L/h}$$

$$\text{WWA} \Rightarrow BOD = 28 \text{ mg/L} \times 100 \text{ L/h} = 2800 \text{ mg/h}$$

$$COD = 280 \text{ mg/L} \times 100 \text{ L/h} = 28000 \text{ mg/h}$$

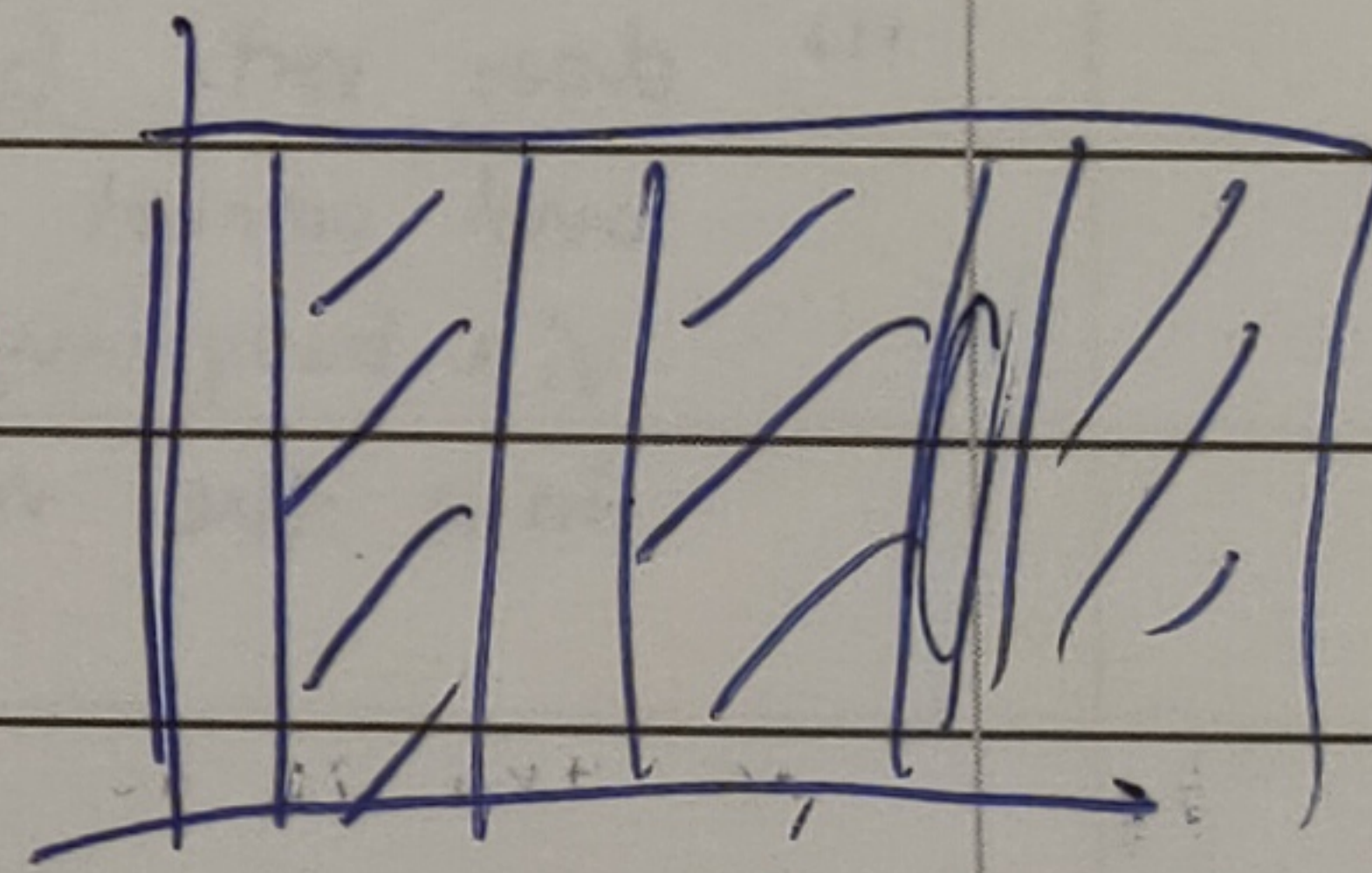
$$\text{WWB} \Rightarrow BOD = 48 \text{ mg/L} \times 400 \text{ L/h} = 19200 \text{ mg/h}$$

$$COD = 96 \text{ mg/L} \times 400 \text{ L/h} = 38400 \text{ mg/h}$$

$$\text{Average BOD} = \frac{(2800 + 19200) \text{ mg/h}}{500 \text{ L/h}} = 44 \text{ mg/L}$$

$$\text{Average COD} = \frac{28000 + 38400}{500} = 132.8 \text{ mg/L}$$

$BOD/COD = 0.33 < 0.5$ (Acceptable treatability)



3) a) i) $Q = 40,000 \text{ m}^3/\text{d}$

$$V = 0.4 \text{ m/s} = 34560 \text{ m}^3/\text{d}$$

$$\text{Area} = \frac{Q}{V} = \frac{40,000}{34,560} = 1.157 \text{ m}^2$$

$$\text{SL height } \sin \theta = 1.157 = 0.5 \Rightarrow 2.315$$

water depth

$$\text{SL height} = \frac{2.315}{\sin 75}$$

$$\text{SL height} = 2.4 \text{ m}$$

$$\frac{A}{V_c} = \frac{A_{bar}}{V_s} \Rightarrow \frac{1.157}{0.4} = \frac{2.4 \times 0.5}{V_s}$$

iii) 50% clogged

$$V_s = 2V_{s \text{ clean}}$$

$$H_L = \frac{1}{C} \left(\frac{V_s^2 - V_c^2}{2g} \right) = \frac{1}{0.6} \left(\frac{1.544^2 - 0.4^2}{2(9.81)} \right) = 0.189 \text{ m}$$

ii) Total bar area = Total clear space

$$V_s = 2V_c$$

$$H_L = \frac{1}{C} \left(\frac{V_s^2 - V_c^2}{2g} \right) = \frac{1}{0.7} \left(\frac{0.712^2 - 0.4^2}{2(9.81)} \right) = 0.0318 \text{ m}$$

$$V_s = 0.415 \text{ m/s}$$

approach velocity = $0.415 \times 2 = 0.83 \text{ m/s}$

$$V_c A = V_s A'$$

$$0.4(2.315)(0.5) = V_s(2.4)(0.5)$$

$$V_s = 0.386 \text{ m/s}$$

$$\text{velocity through clean bar screen} = 0.386 \times 2 = 0.772$$

total bar area = total clear space

before treatment
after treatment, before storage

1) b) Chlorine is added at 2 stages, namely primary & secondary. Primary stage refers to the inactivation of microorganism in water while in secondary stage, chlorination is use to maintain a disinfectant residual in the treated water distribution system, preventing biological growth in water pipes.

The importance of chlorination breakpoint in the disinfection process is to identify the point where chlorine demand is met and that chlorine added beyond the breakpoint forms HOCl in direct proportion to the amount of chlorine added, thus available as free chlorine. This is important in the calculation of chlorine dosage needed to maintain a required chlorine residual for the disinfection process.

Important for effective disinfection (produce free chlorine)
control taste/odour (avoid under-chlorination \Rightarrow chloramines)

ii) $LRV = \log [C_i/C_e] d c.t$

$\log [C_i/C_e] = k C t$

For $C = 0.25, t = 40$

$\log [C_i/C_e] = 0.4(0.25)(40)$

For 99.9% removal

$\log \left[\frac{100}{0.001} \right] = k(0.5)(10)$

$\log [C_i/C_e] = 4$

$C_i/C_e = 10^6$

$\frac{C_i - C_e}{C_i} = 0.999$

$3 \times = 5k$

$\frac{C_i}{C_e} = \frac{10000}{0.001}$

$C_e/C_i = 0.000001$

$1 - C_e/C_i = 0.999$

$k = 0.4 \times 0.6$

$C_e = 0.01 \times 0.001$

$1 - C_e/C_i = 0.999999$

$C_e/C_i = 0.001$

$100 - 0.01 = 99.99\% \text{ removal}$

removal = 99.9999%

$\log_{10} (C_i/C_e) = 3$

c) UF is used prior to RO as UF have a bigger pore size compared to RO. It is target to remove all the particles and microorganisms by straining so that the wastewater entering RO will only contains dissolve solids. This prevents the clogging up of RO tanks.

RO utilise higher pressure so will clog up fast if have solids present

ii) $Q = 1000 \text{ m}^3/\text{h}$

$Q_{P,UF} = Q_{F,RO}$

$Y_{UF} = 90\%$

$Y_{UF} = \frac{Q_p}{Q_f}$

$Y = \frac{Q_p}{Q_f} = 0.9$

$Y_{RO} = 75\%$

$90\% = \frac{Q_p}{1000}$
 $Q_p = 900$

$Q_{F,UF} = 1000 \text{ m}^3/\text{d}$

$Q_p = 0.9 Q_f$

$Y = \frac{Q_p}{Q_f}$

For RO, feed is from UF

$Y_{RO} = \frac{Q_p}{Q_f}$

$Y_{RO} = \frac{Q_p}{Q_f} = \frac{Q_p}{0.9 Q_{F,UF}} = 75\%$

$75\% = \frac{Q_p}{900}$

$Q_p = \text{water production} = 675 \text{ m}^3/\text{h}$

~~sedimentation~~

2) b) $\frac{h}{L} = \frac{1.067 C_0 v^2}{\psi g d f^4}$

$v = 50 / (24 \times 3600)$
 $= 5.79 \times 10^{-4} \text{ m/s}$

Anthracite,

$\frac{h}{L} = 1.067 (4) \frac{(5.79 \times 10^{-4})^2}{0.9(9.81)(0.001)(0.5)^4}$

$Re = \frac{\psi \rho d v}{\mu}$

$\frac{h}{L} = 0.0266$

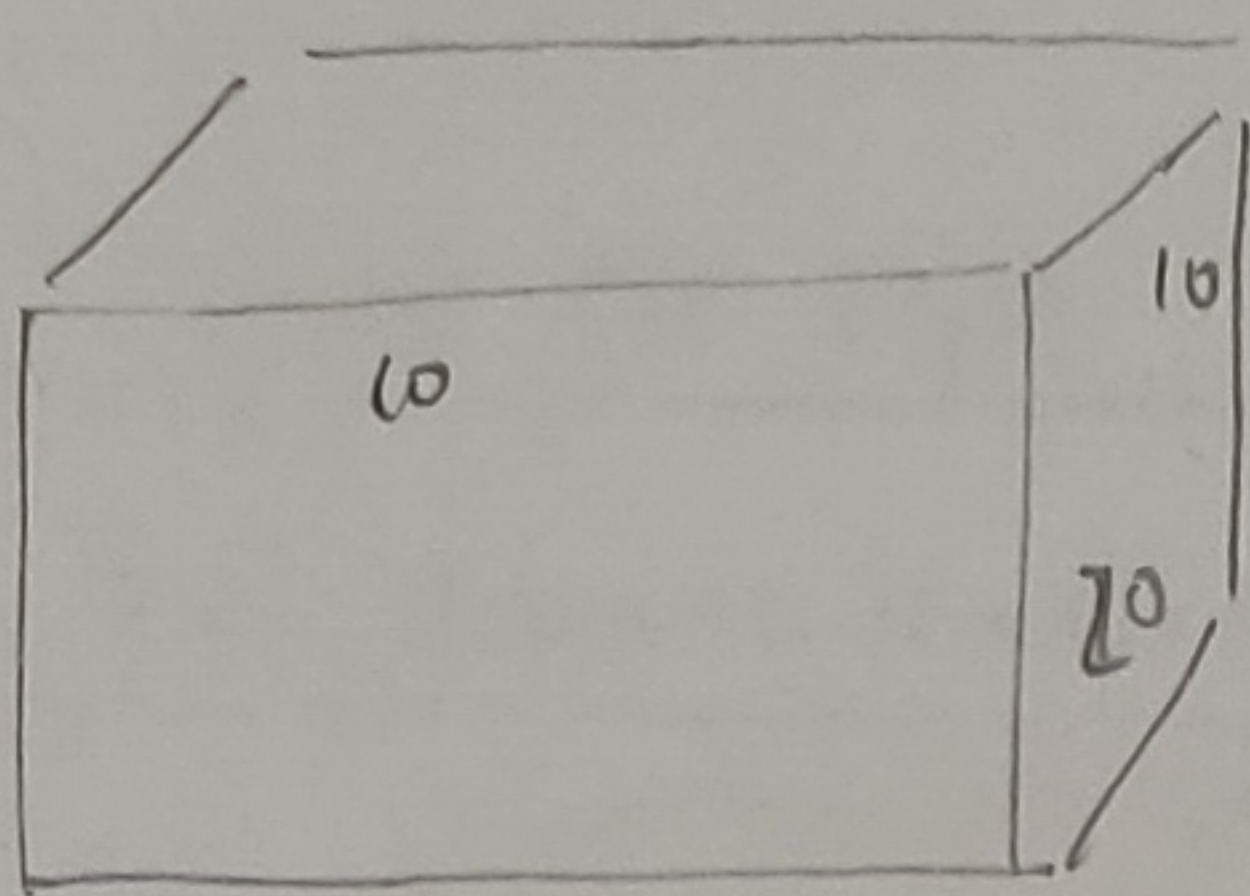
$= \frac{(0.9)(1000)(0.001)(5.79 \times 10^{-4})}{0.89 \times 10^{-5}}$

$h = 0.0133$

$= 0.59 < 1$

$C_0 = \frac{24}{Re} = 41$

2) (a) i)



A - $\rho_A = 1500 \text{ kg/m}^3$
 $X_v = 60\%$

square - 10×10

$$V_0 = \frac{Q}{A_{\text{surface}}}$$

$$V_0 = \frac{1000 \text{ m}^3}{1 \times 3600}$$

$$= 2.78 \times 10^{-3} \text{ m/s}$$

$$X_r = \frac{V_s}{V_0} = 0.6$$

$$V_s = 1.67 \times 10^{-3} \text{ m/s}$$

for tank with length l & width w (assume Q same)

$$V_0 = \frac{1000}{3600}$$

$$V_0 = 1.39 \times 10^{-3} \text{ m/s}$$

$$X_r = 106\% \text{ (since } V_s > V_0 \text{)}$$

ii) $d_{ps} = 15$

density = 1500 kg/m^3

$d_{ps} = 50 \mu\text{m}$

$h_s = 10 \text{ m}$

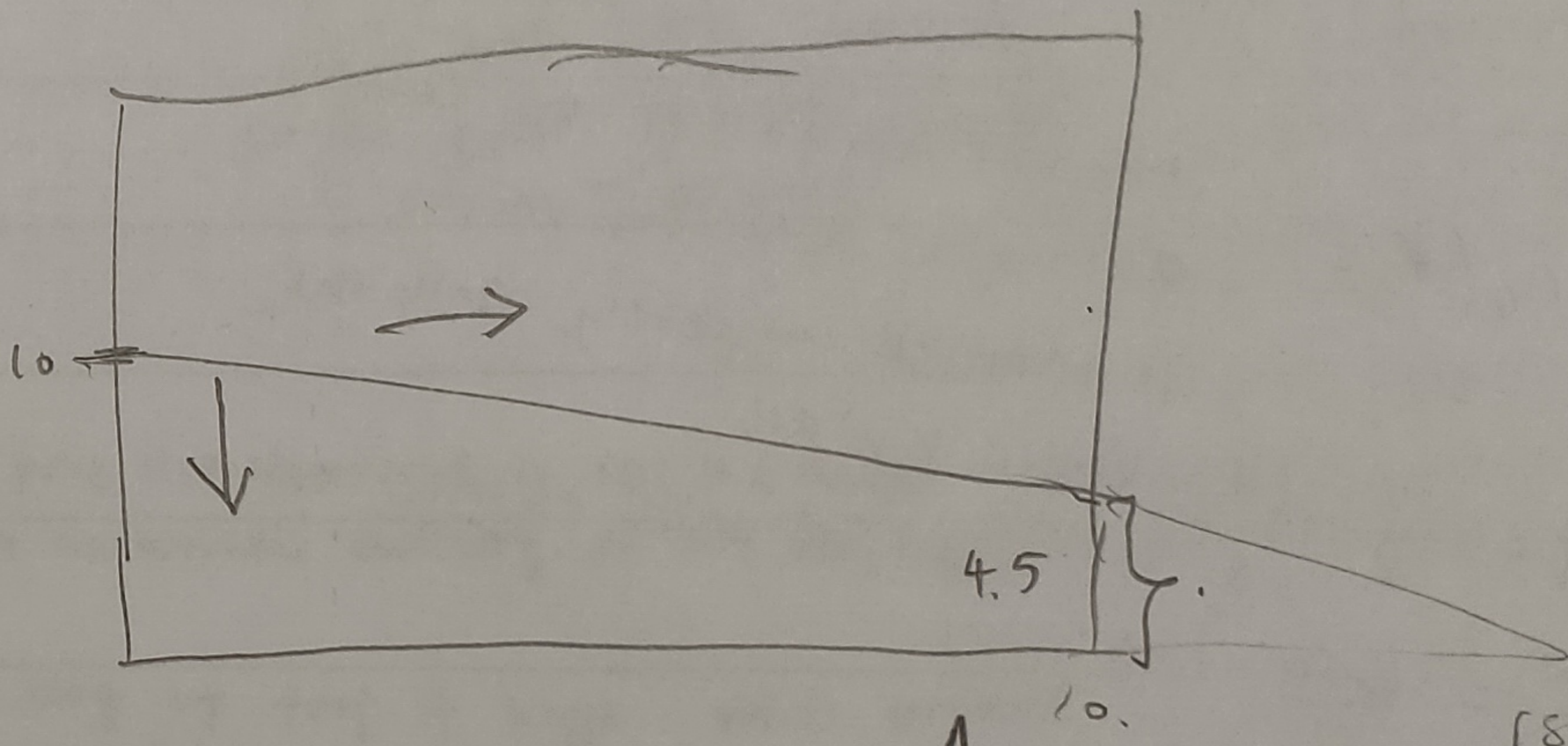
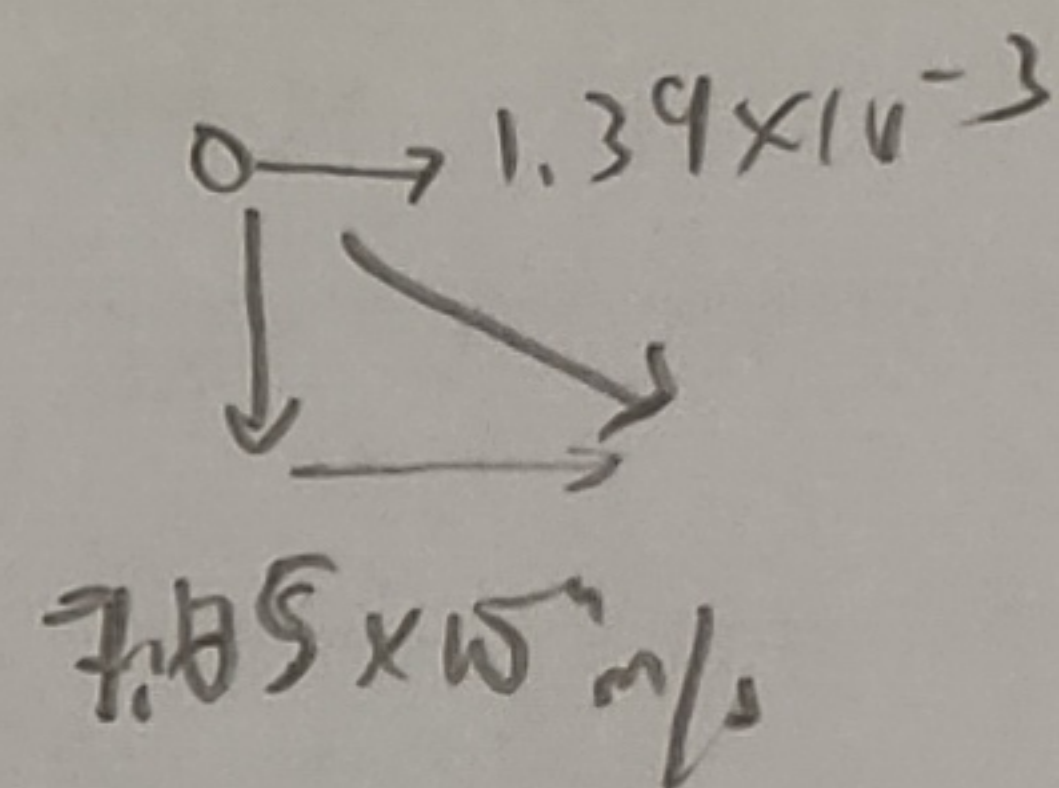
$$X_r = \frac{h_s}{h_0} = \frac{10}{20} = 50\%$$

$$V_s = \frac{9.81 (1500 - 100) (50 \times 10^{-6})^2}{18 (0.89 \times 10^{-3})}$$

$$= 7.65 \times 10^{-4} \text{ m/s}$$

$$X_r = \frac{7.65 \times 10^{-4}}{2.78 \times 10^{-3}} = 0.275 = 27.5\%$$

$$V_t = \frac{Q}{A_{\text{cross}}} = 1.39 \times 10^{-3} \text{ m/s}$$



$$t_r = \frac{h_0}{V_0} = \frac{20}{2.78 \times 10^{-3}} = 7194 \text{ s}$$

$$V_s \times t = 5.5 \text{ m}$$

$$10 - 5.5 = 4.5 \text{ m}$$

Sand,
 $Re = \frac{\rho v (\psi dp)}{\mu}$

$$= \frac{(5.99 \times 10^{-4})(1000)(0.75)(0.0005)}{0.893 \times 10^{-3}}$$

$$= 0.243 < 1$$

$$Re < 1$$

$$Co = \frac{24}{Re} = 98.71$$

$$V_b = V_s (f_e)^{4.5}$$

$$0.1 V_s = V_s (f_e)^{4.5}$$

$$0.1 = f_e^{4.5}$$

$$f_e = 0.6$$

$$\left(\frac{1-f}{1-f_e}\right) = \frac{L_e}{L} = 1.4$$

$$\frac{1-f}{1-0.6} = 1.4$$

$$f = 0.44$$

$$f = f_1 \left(\frac{L_1}{L_1+L_2}\right) + f_2 \left(\frac{L_2}{L_1+L_2}\right) = 0.44$$

$$0.5 \left(\frac{0.5}{0.5+0.3}\right) + f_2 \left(\frac{0.3}{0.5+0.3}\right) = 0.44$$

$$f_2 = 0.34 //$$

$$\frac{h}{L} = 1.067 (98.71) \frac{(5.79 \times 10^{-4})^2}{9.81 \times 0.0005 \times 0.75 \times 0.344}$$

$$\frac{h}{L} = 0.718$$

$$h = 0.215 \text{ m}$$

total head loss

$$= 0.215 + 0.0133$$

$$= 0.2283 //$$

ii) To increase/maximize the filtration time before the acceptable effluent std is exceeded, one has to use coarser medium as this way will slow down the clogging rate of the filter and thus the filter remains to have higher effluent stds. Also, only must decrease the bed depth to lower the head loss.

↳ finer medium (capture small particles)

increase bed depth (achieve depth filtration)

high dosage of coagulant (small particles coagulate to form bigger flocs to be captured by media filter)

Decrease filtration rate (slow down rate of clogging)

function? → Coagulation, flocculation, precipitation, oxidation?

L 3) b) The 3 functions of chemical treatment are

coagulation & flocculation - destabilise & aggregation of SS so easier to settle
precipitation - precipitate soluble solids (P, heavy metals) so to remove them
oxidation - reduce ~~iron~~ metals, removing recalcitrant org matter
"Lignocellulose"

↑
improve treatability
eliminate inhibitory effect to microbial growth
reduce/eliminate toxicity

→ remove solids (turbidity)

c) i) DAF starts off by dissolving air in water or wastewater under pressure (e.g. 3-4 - 3.8 atm) and then releasing the air at atmospheric pressure in the floatation tank or basin. Next, the released air will instantaneously form tiny bubbles of 30-120 μm. The tiny bubbles will then adhere to suspended matter, causing the suspended matter to float to the surface of water. The floats then is removed by a skimming device.

ii) Gravity sedimentation depends on the settleability of the suspended matter while DAF does not. Gravity sedimentation only can remove suspended matter with high settleability and cannot remove particles of lower density than liquid but DAF can removed them via buoyancy. Gravity sedimentation does not involve the introduction of air/gas into the water but DAF does.

iii) $A = \frac{Q}{V}$

If recycle stream is present, $Q = Q + Q_r$ (consistly of 2 components) ⇒ high Q value which cause an increase in the designed surface area!

4) a) Area, $A = \frac{\pi (20)^2}{4} = 100\pi \text{ m}^2$

Volume $V_1 = 100\pi \times 2 = 200\pi \text{ m}^3$

$Q = 4000 \text{ m}^3/\text{d}$

BOD load = $200 \times 10^{-6} \text{ kg/L} \times 4000 \text{ m}^3/\text{d} \times 1000 \text{ L/m}^3$
= 800 kg/d .

BOD Volumetric Loading Rate = $\frac{800}{200\pi} = 1.273 \text{ kg/m}^3 \cdot \text{d}$ ||

Hydraulic loading rate = $\frac{Q+Q_r}{A} = \frac{(1+R)Q}{A}$

For $R=1$, $HLR = \frac{2Q}{A} = \frac{2(4000)}{100\pi}$

= $25.46 \text{ m}^3/\text{m}^2 \cdot \text{d}$ ||

4) a) $R=1.0$
 $F = \frac{1+1}{(1+\frac{1}{10})^2} = 1.65$
 $E = \frac{100}{1+0.4432 \sqrt{\frac{100}{1.65(2007)}}}$
 $= 71.98\%$

b) $COD_{in} = COD_{eff} + COD_{cells} + COD_{methane}$ (negligible)

$COD_{methane} = COD_{in} - COD_{eff} - COD_{cells}$

$COD_{in} - COD_{eff} = 4000 \text{ g/m}^3 \times 2000 \text{ m}^3/\text{d} \times 0.95 = 7600 \text{ kg COD/d}$

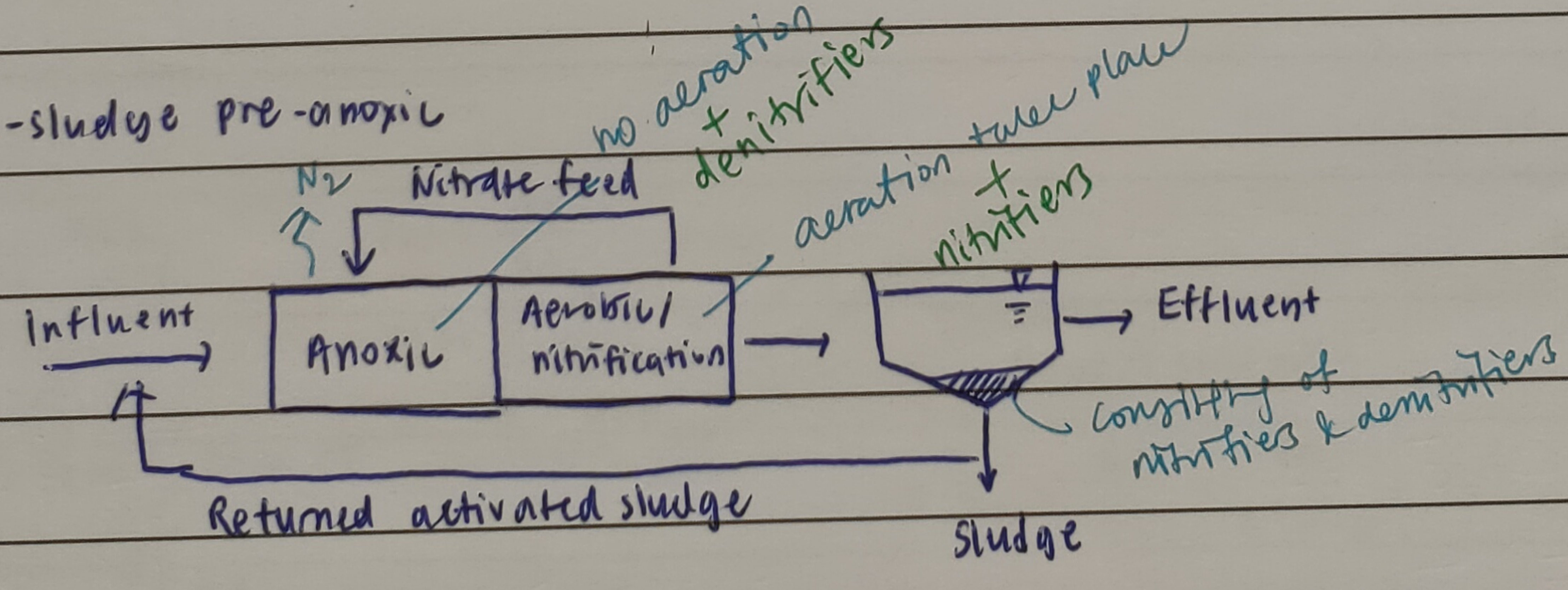
biomass production = $0.40 \text{ L VSS/g COD} = 400 \text{ g VSS/g COD}$

~~$COD_{cells} = 7600 \text{ kg COD/d} \times 0.4 \text{ g VSS/g COD} \times 1.42 \text{ g COD/g VSS}$
 $= 4316.8 \text{ kg/d}$~~ $COD_{cells} \approx 0$

$COD_{methane} = 7600 = 7600 \text{ kg/d}$

Volumetric rate = $7600000 \text{ g/d} \times 0.4 \text{ L/g COD}$
 $= 3040 \text{ m}^3/\text{d}$

c) Single-sludge pre-anoxic



evaporable
releases
removed

Pre-anoxic process involves having denitrifying reactor before nitrification. The influent will flow into a tank of anoxic condition for denitrification. The content of the first tank will overflow into the next tank, which is aerobic and hence conducive for nitrification. Here, nitrification takes place to convert NH_4^+ ions to NO_3^- ions. Then NO_3^- will be feed back into the first tank for denitrification, that is conversion of NO_3^- ions to N_2 gas. For denitrification, the electron donor comes from the influent flow, which also includes the sludge that is returned to the influent flow to provide sufficient org & heavy matter for denitrification.

from the clarifier

4) d) i) Five types of MSW includes; plastics, metals, glass, food waste and paper & paperboard.

ii) Primary pollutants are pollutants emitted directly from air pollution sources, such as CO, SO₂.
Secondary pollutants are pollutants that are formed in the atmosphere via chemical reactions, such as O₃ and HCl.

iii) O₃ can be good or bad, depending on the level of altitude the gas is present at.

At ground level, O₃ is bad ozone as it contributes to smog formation & causes health and environmental effects.

However, at stratosphere, O₃ shields us from UV radiation, and here O₃ is good.

Chemical reaction between NO_x and VOC in presence of heat & sunlight

