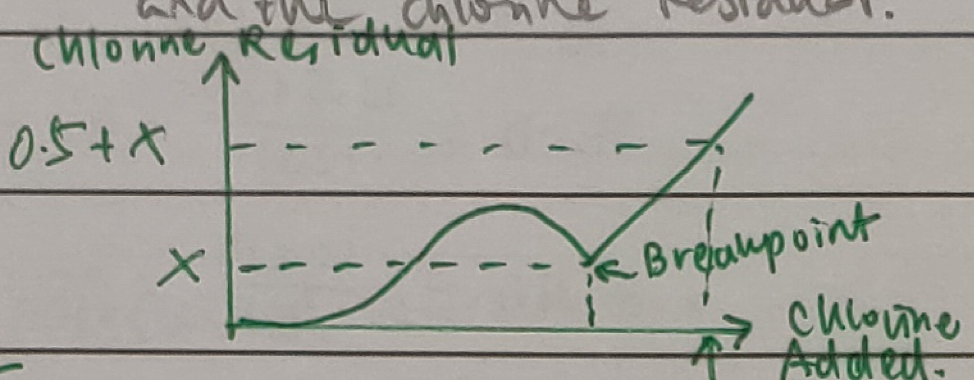
2017/18.

1) a) i) To maintain the concentration of free chlorine in water at 0.5mg/L, one has to identify the breakpoint of the chlorination process. Beyond the breakpoint, all chlorine added will react with water to form HOCl in direct proportion to the amount of chlorine added and available as free chlorine. This is because all the chlorine demand are met such as to react with compounds in water and react with all dissolved ammonia.

As chlorine dosage equals to chlorine demand plus chlorine residual, ~~to have 0.5mg/L of free chlorine~~ and total residual equals to free residual plus combined residuals, to have 0.5mg/L of free chlorine in water, one has to find out the ~~chlorine at~~ amount of combined chlorine at breakpoint to get the chlorine residual required. Then, chlorine dosage required is found by summing up the chlorine demand and the chlorine residual.

~~Combined~~ chlorine residual remains constant after breakpoint

Total residue = combined residue + free residual = combined + 0.5mg/L ⇒ read off the value from the curve to find the required dosage



Free chlorine – HOCl disinfectant that has yet to react with the compounds in the ww (not utilised)

To maintain, need to identify breakpoint ← residual + chlorine dosage / demand

Beyond breakpoint, chlorine added proportional to free chlorine amount

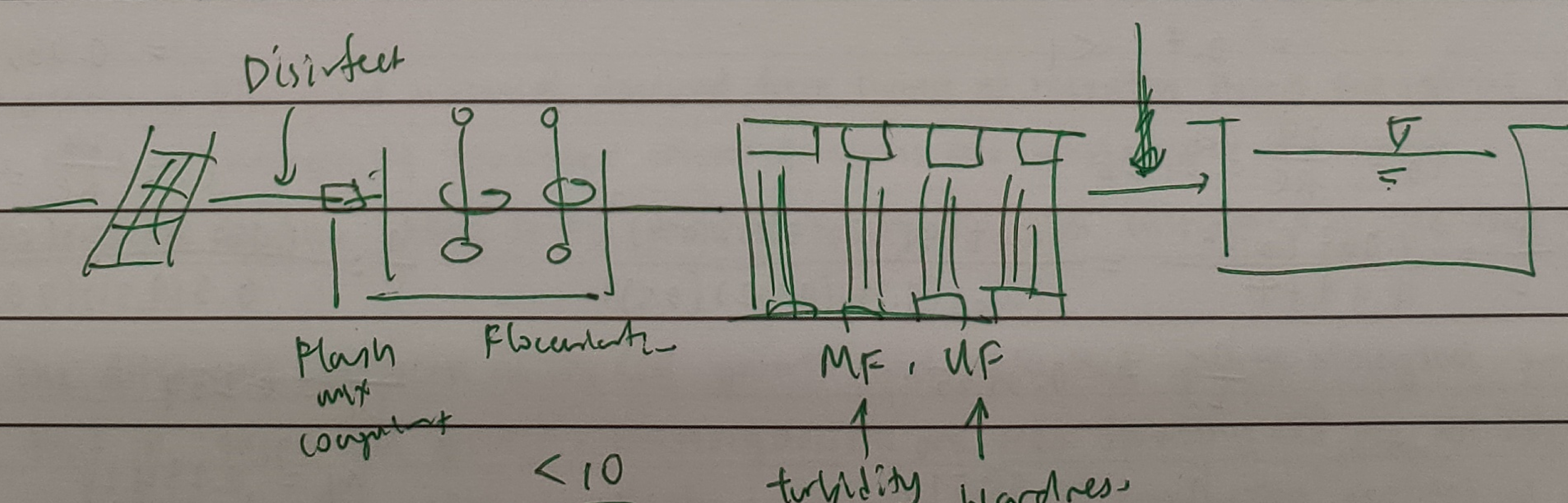
ii) The weakness of chlorination is that it forms disinfection by products that are undesirable. Also, it is not effective in removing protozoa as protozoa like Giardia & Cryptosporidium are resistant to chlorine.

The advantage of chlorination is that it is effective, have residual stability and it is low cost.

The disadvantages of UV disinfection is that reactivation of injured microorganism through self repairing might happen. Also, there will be interference from particles in water causing refraction, reflection & scattering of UV light, ~~causing~~ reducing the effectiveness of the treatment. Lastly, the design of UV reactors has a short residence time and may have the issue of dispersion & short circuiting.

The advantage of UV disinfection is that it is useful in inactivating Giardia & cryptosporidium.

b) ~~Guild~~ Guidelines <5 NTU <15 C.U. TDS < 500 mg/L



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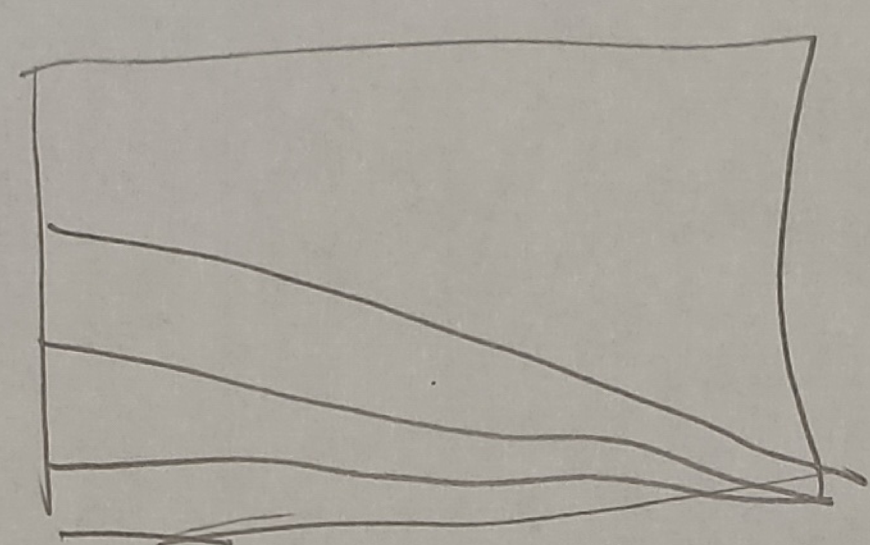
1) a) i)

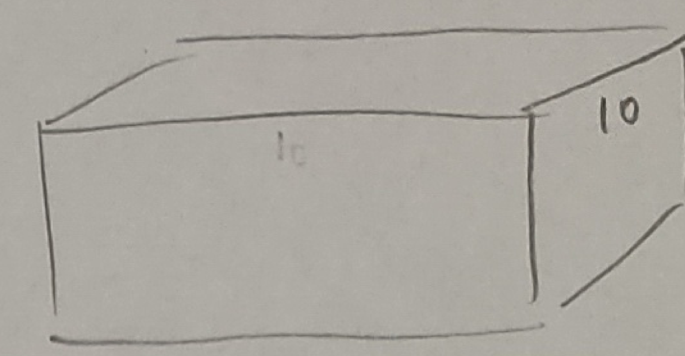
ii)

b). Requirements : small footprint
less chemical usage.
high treatment efficiency.

20 NTU
Hardness = 250 mg/L as $CaCO_3$
TDS = 300 mg/L
virus & e-coli



2) a) i) pop = 100,000
consumption = 150 lpcd.



A = 30 μm , 1800 kg/m³ $X_r = 67.5\%$

B = 15 μm , 1500 kg/m³ .

C ⇒ $V_{sc} = 0.001$ m/s.

i) $V_{SA} = \frac{9.81(1800-1000)(30\times10^{-6})^2}{18(0.893\times10^{-3})}$

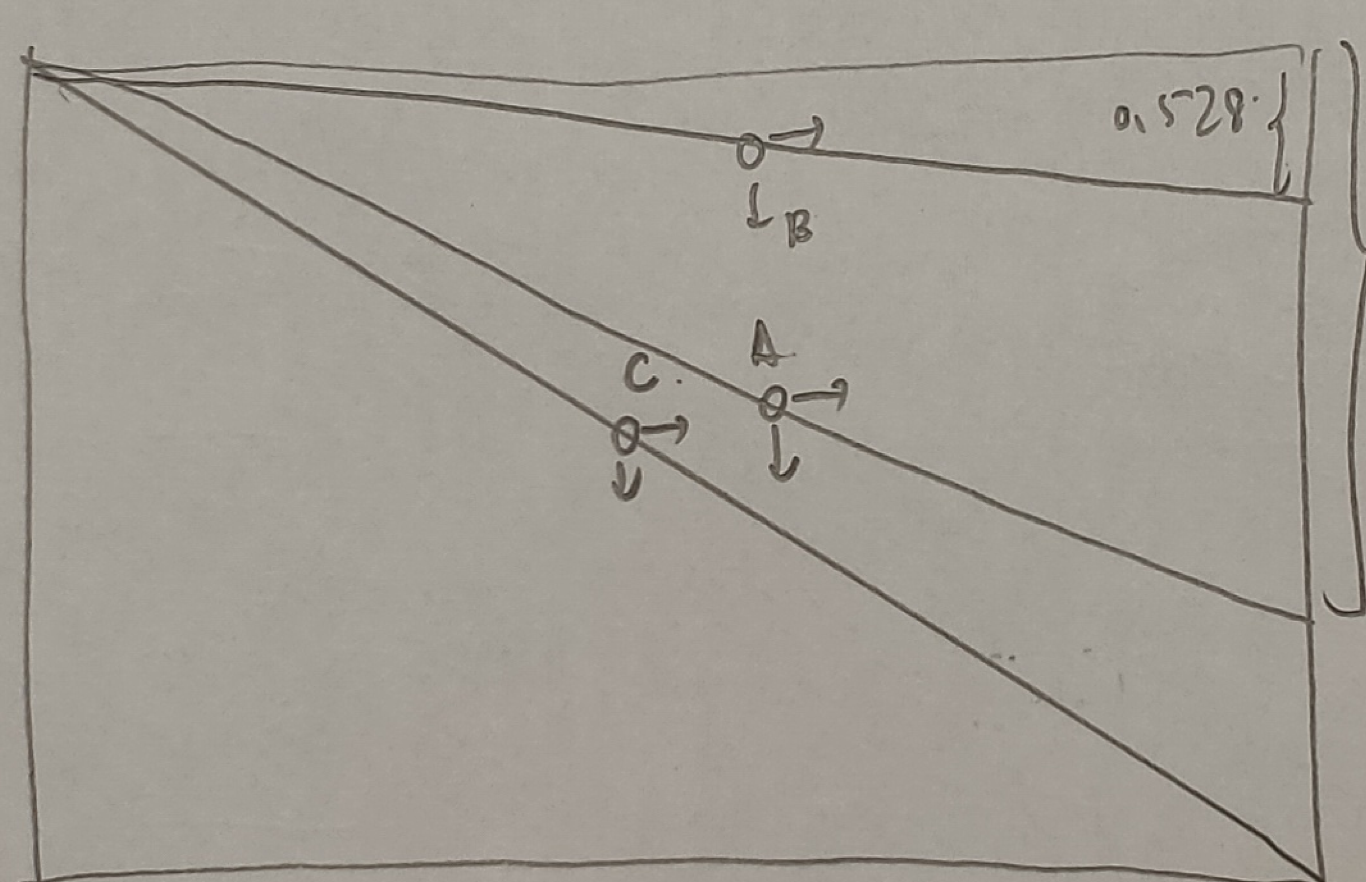
$= 4.394\times10^{-4}$ m/s.

$X_r = \frac{V_{sA}}{V_o} = 0.675$

$V_o = 6.51\times10^{-4}$ m/s.

$V_{SB} = \frac{9.81(1500-1000)(15\times10^{-6})^2}{18(0.893\times10^{-3})}$

$= 6.87\times10^{-5}$ m/s



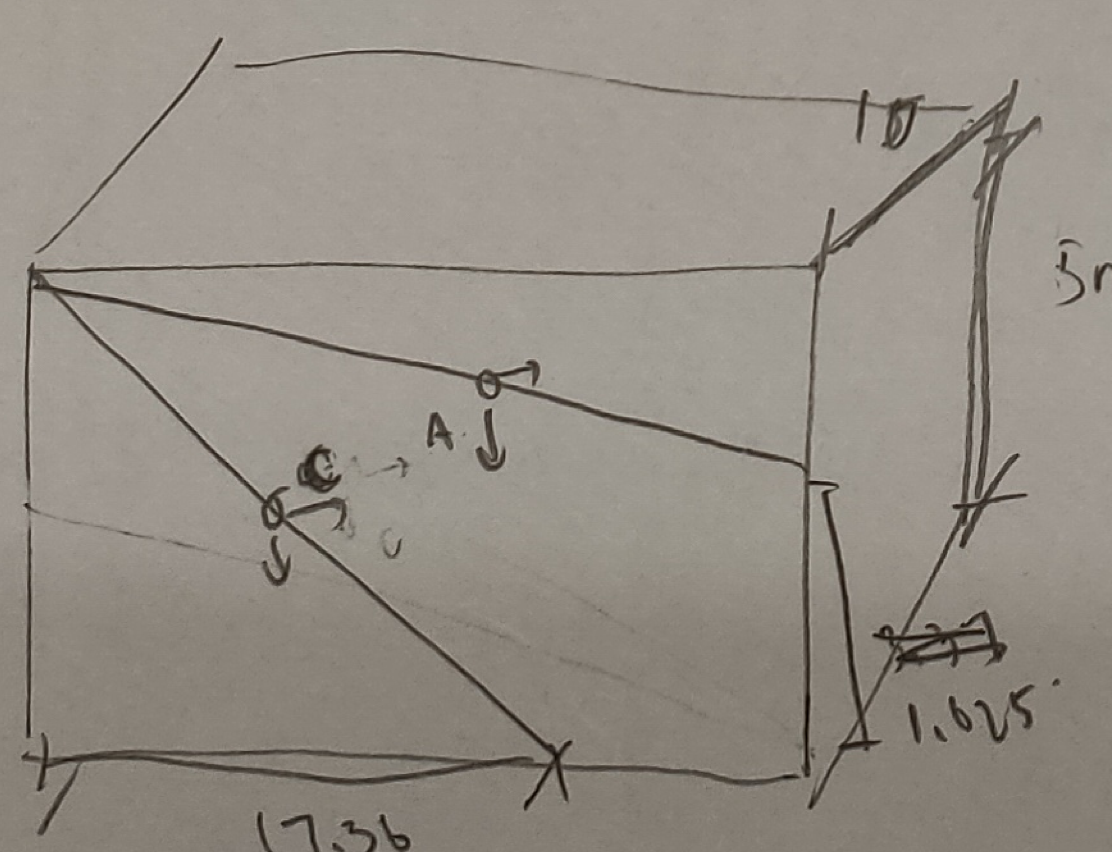
$X_r = \frac{V_{sB}}{V_o} = 0.105$

$= 10.55\%$

Since $V_{sc} > V_o$
$\therefore X_r = 100\%$

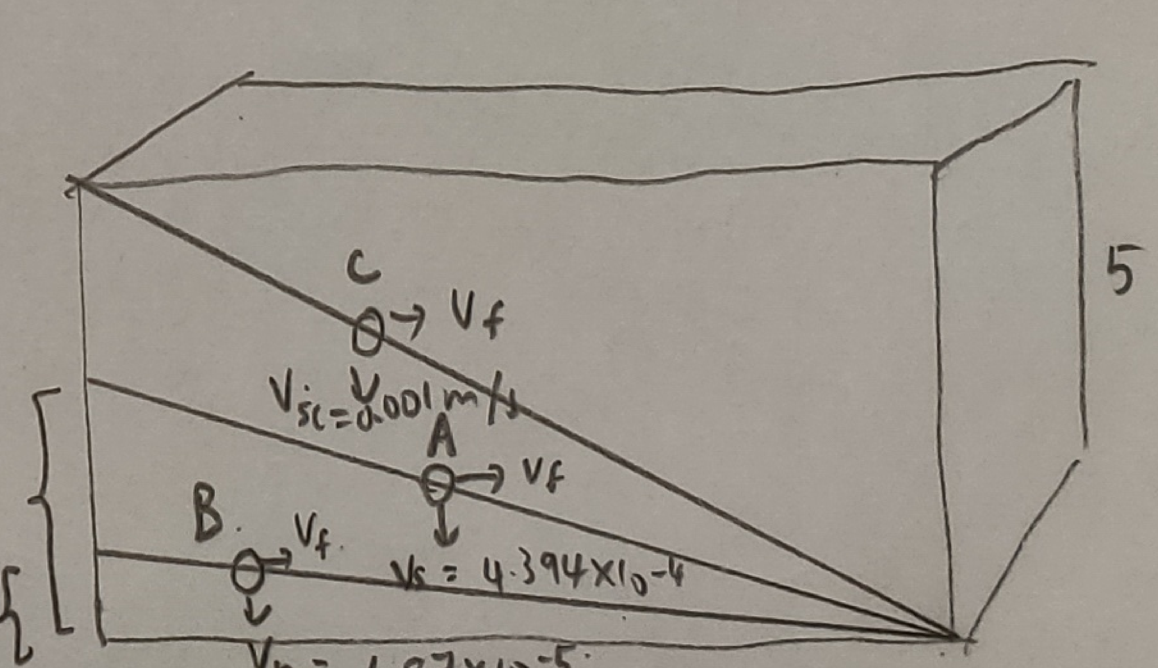
~~$X_r = \frac{V_{sc}}{V_o}$~~

ii).



$\frac{h_o}{V_o} = t$

$\frac{5}{6.51\times10^{-4}} = 7680$ s



V_f = ???

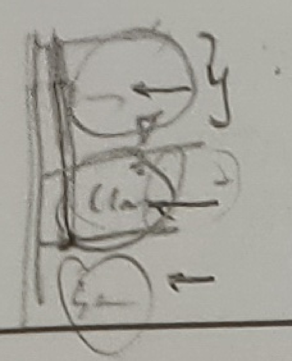
$V_o = \frac{h_o}{t}$

$t = \frac{h_o}{V_o}$

$= 7680$ s.

$V_f = \frac{Q}{A_{cross}} = \frac{150\times100\,000\times\frac{1}{1000}\times\frac{1}{3600\times24}}{10\times5}$

$V_f = 3.472\times10^{-3}$ m/s



$18(8)$
$+ (16-10)(\text{?})\text{?} = K a \text{(OH)}$ clay $= \sigma_{vo} - 2C_u$ (sand-drain)
$+ (17-11)(3)$

c) $TON = 45 mg/L$
$C_6H_{14}N_2O_2 = 200 mg/L$

$C_6H_{14}N_2O_2 + 7O_2 \rightarrow 6CO_2 + 2NH_3 + 4H_2O$
146   32x7   12x6   2x14
200 mg/L

$TON = (2\times14)/146 \times 200 mg/L = 38.36 mg/L$

$ThOD = \frac{32\times7}{146} \times 200 = 306.85 mg/L$

$TOC = \frac{12\times6}{146} \times 200 = 98.63 mg/L$

$C_{10}H_{19}O_3N + 12.5O_2 \rightarrow 10CO_2 + NH_3 + 8H_2O$
201   12.5x32   10x12   14
y mg/L

$TON = 45 - 38.35 = 6.64 mg/L$

$\frac{14}{201} \times y\ mg/L = 6.64 mg/L$

$y = 95.33 mg/L$

$ThOD = \frac{12.5\times32}{201} \times 95.33 = 189.71 mg/L$

$TOC = \frac{10\times12}{201} \times 95.33 = 56.91 mg/L$

$ThOD = 306.85 + 189.71 = 496.56 mg/L$

$TOC = 98.63 + 56.91 = 155.54 mg/L$

ii) to maximise filtration time, use finer medium, increase bed depth, apply higher dose of coagulant and decrease filtration rate.

$V_b = 0.001$

0.01
0.01

2) a) Sedimentation

b) i) head loss = 0.2   depth of filter bed, L $= L_x + L_y$

Filtration rate $= 45/(24\times3600) = 5.21\times10^{-4}$ m/s

For particle X,
$Re = \frac{\psi \rho d V}{\mu}$
$= \frac{0.6(1000)(0.002)(5.21\times10^{-4})}{0.893\times10^{-3}}$
$= 0.7 < 1$

For particle Y,
$Re = \frac{\psi \rho d V}{\mu}$
$= \frac{0.8(1000)(0.001)(5.21\times10^{-4})}{0.893\times10^{-3}}$
$= 0.4667 < 1$

$0.5\left(\frac{L_x}{L_x+L_y}\right)$

$C_D = \frac{24}{Re} = 34.28$

$\frac{h}{L} = \frac{1.067 C_D V^2}{\psi g d f^4} = \frac{1.067(34.28)(5.21\times10^{-4})^2}{(0.6)(9.81)(0.002)(0.5)^4}$

$\frac{h_x}{L_x} = 0.0135$

$h_x = 0.0135 L_x$

$C_D = \frac{24}{Re} = 51.42$

$\frac{h}{L} = \frac{1.067(51.42)(5.21\times10^{-4})^2}{0.8(9.81)(0.001)(0.3)^4}$

$\frac{h_y}{L_y} = 0.234$

$h_y = 0.234 L_y$

Head loss $= h_x + h_y = 0.2$
$0.0135 L_x + 0.234 L_y = 0.2$ — (1)
$0.0135(0.9L) + 0.234(0.1L) = 0.2$

$0.01215L + 0.0234L = 0.2$
$0.03555L = 0.2$
$L = 5.626$ m

Bed expansion = 30%

$\frac{L_e}{L} = \frac{1-f}{1-f_e} = 1.3$

$V_b = V_s(f_e)^{4.5}$
$0.1 V_s = V_s(f_e)^{4.5}$
$f_e = 0.6$

$f = 0.5\left(\frac{L_x}{L}\right) + 0.3\left(\frac{L_y}{L}\right)$

$1 - \left[0.5\left(\frac{L_x}{L}\right) + 0.3\left(\frac{L_y}{L}\right)\right] = (1-0.6)1.3$
$0.48 = 0.5\left(\frac{L_x}{L}\right) + 0.3\left(\frac{L_y}{L}\right)$
$0.48L = 0.5L_x + 0.3(L - L_x)$
$0.48L = 0.5L_x + 0.3L - 0.3L_x$
$0.18L = 0.2L_x$
$L_x = 0.9L$
$L_y = L - 0.9L = 0.1L$

$\frac{3\,g}{1000\,g} \rightarrow \frac{3000\,mg}{1\,l}$

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3) a) Without pressurised recirculation.

$\frac{A}{S} = \frac{1.3\,Sa\,(fP-1)}{Sa}$

~~$0.008 = \frac{1.3\,(18.7)(0.5P-1)}{3000}$~~

~~$P = 3.974$ atm~~

~~$3.974 = \frac{P + 101.35}{101.35}$~~

$P = 301.41$ kPa //

Sa
$0.3\% \rightarrow \frac{3g}{1000g} = \frac{3g}{1000\,ml} = \frac{3g}{1L} = \frac{3000\,mg}{L} = 3000\,mg/L$

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

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

$= \frac{400\,m^3/d \times 1000\,L/m^3}{8\,L/m^2.min \times 60 \times 24\,min/d}$

$= 34.72\,m^2$ //

With pressurized recirculation

$\frac{A}{S} = \frac{1.3\,Sa\,(fP-1)R}{Sa\,Q}$ ← m^3/d

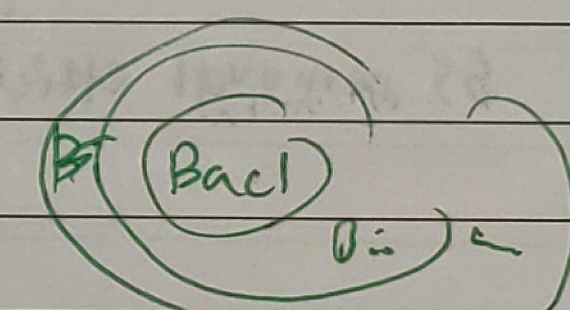
~~$0.008 = \frac{1.3(18.7)(0.5P-1)R}{3000(400)}$~~

$P = \frac{275 + 101.35}{101.35} = 3.71$ atm

$0.008 = \frac{1.3(18.7)(0.5 \times 3.71 - 1)R}{3000(400)}$

$R = 461.87\ m^3/d$

$V_o = \frac{Q}{A}$ ← $(Q + Q_r)$



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

$= \frac{(400 + 461.87) \times 1000}{8 \times 1440}$

$= 74.82\ m^2$ //

what's the diff between the two terms

b) Biomass is biological material derived from living or recently living organisms. In WWT, it refers to biologically generated microorganisms for wastewater treatment.
Activated sludge refers to the mass of microorganism cultivated in the treatment process.

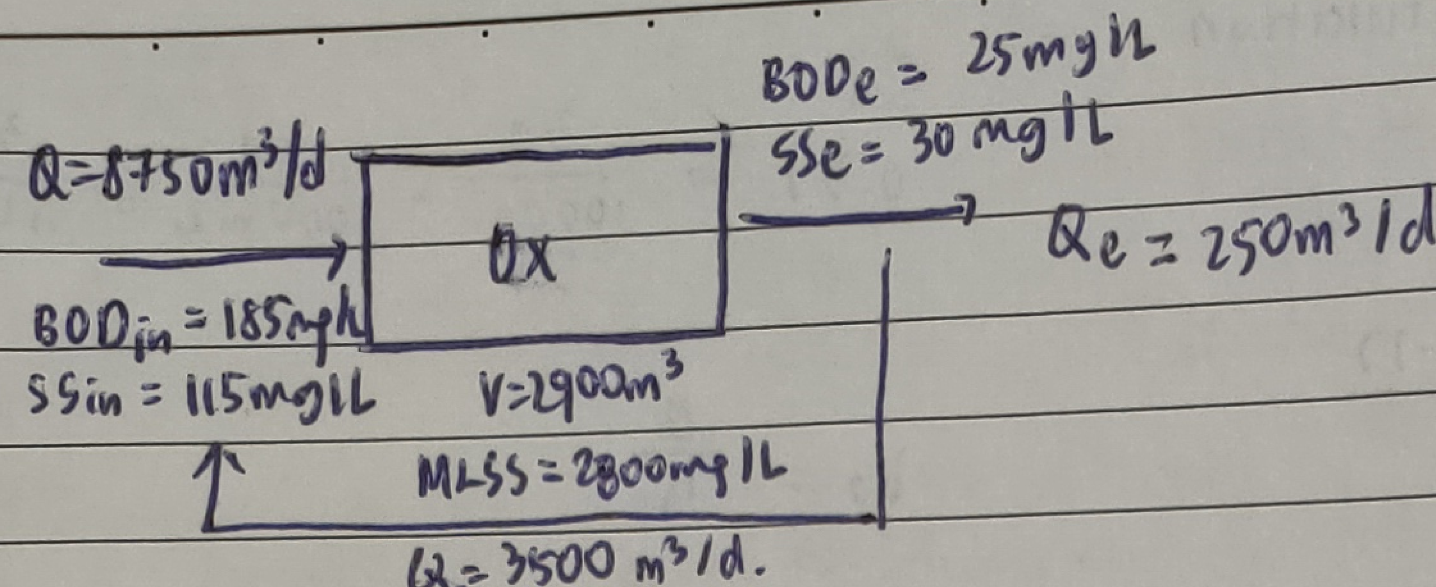
The difference between suspended growth and attached growth biological process is that in suspended growth, microorganisms are free floating and are not attached to a surface /media while in attached growth, the microorganism resides at a surface in the form of biofilm.
The microorganism in suspended growth moves & mix with the sludge while the microorganism in attached growth does not move with the sludge but remained attached to a media.

return to influent
return to prim. clarifier

pretreatment to ~~reduce~~ limit solid content (clog)

A'ZONE

3) c)



i) $\frac{F}{M} = \frac{QS_0}{VX}$

$= \frac{8750 \times 185}{2900 \times 0.85 \times 2800} = 0.235$ kg BOD / kg MLVSS · d

ii) $HRT = \frac{V}{Q}$

$= \frac{2900}{8750} = 0.33\,d$

$= 7.95$ hours

iii) BOD removal efficiency $= \frac{185-25}{185} \times 100\%$

$= 86.5\%$

SS removal efficiency $= \frac{115-30}{115} \times 100\%$

$= 73.9\%$

oxygen as electron acceptor (oxidizing agent)

d) Both nitrification & denitrification are biological nitrogen removal processes. Nitrification is the conversion of ammonium, NH_4^+ to a nitrate, NO_3^- ion, through a two step process, that is NH_4^+ to NO_2^- and NO_2^- to NO_3^-. The process is mediated by nitroso-bacteria in the 1st step & nitro-bacteria in the second step. An aerobic condition with high O_2 is required to carry out nitrification as O_2 is used as oxidizing agent. (electron donor) → reducing agents.
Denitrification is the conversion of NO_3^- ions to nitrogen gas N_2 with the help of denitrifiers. Operating conditions ~~...~~ required are low O_2 (anoxic condition) with high C as the process uses organics & inorganics as electron donors.
organic compounds

Denitrifiers - facultative aerobes, use NO_3^- & NO_2^- as electron acceptor when DO is low
- use org & inorg as electron donor

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4) a) BOD loading = 610 kg/d

Area = $\pi(26)^2/4$ = 530.93 m^2

volume = Area x 2 = 1061.89 m^3

BOD volumetric loading rate = $\frac{610}{1061.89}$

= 0.575 kg/m³.d //

Hydraulic loading rate = $\frac{Q+Q_r}{A}$

= $\frac{(1+R)6500}{530.93}$

For R = 0, HLR = 12.24 m³/m².d //

For R = 1, HLR = 24.49 m³/m².d //

For R = 0,

$F = \frac{1+0}{(1+\frac{0}{10})^2} = 1$

$E = \frac{100}{1+0.4432\sqrt{\frac{W}{FV}}}$ kg/d

$= \frac{100}{1+0.4432\sqrt{\frac{610}{1(1061.89)}}}$

= 74.85 %

For R = 1

$F = \frac{1+1}{(1+\frac{1}{10})^2} = 1.65$

$E = \frac{100}{1+0.4432\sqrt{\frac{610}{1.65\times1061.89}}}$

= 79.27 %

b) Advantages of anaerobic treatment process compared to aerobic is that no oxygen is required for anaerobic, which is a huge cost savings as well as energy saving. In fact, anaerobic process produce methane and/or H_2 as byproducts which are source of energy, hence instead of using energy, it produces it.
Anaerobic process also allow high VLR to be applied and hence only a small reactor volume is required.
Also, anaerobic process has lower sludge production which saves on sludge treatment as well as require low nutrient compared to aerobic.

c) $\frac{M_s}{\rho_s} = \frac{M_v}{\rho_v} + \frac{M_f}{\rho_f}$

$\frac{M_s}{\rho_s} = \frac{0.6M_s}{0.97} + \frac{0.4M_s}{2.9}$

$S_s = 1.284$

$\frac{M_{sl}}{S_{sl}} = \frac{M_s}{S_s} + \frac{M_w}{\rho_w}$

$\frac{M_{sl}}{S_{sl}} = \frac{0.05M_{sl}}{1.284} + \frac{0.95M_{sl}}{1}$

$S_{sl} = 1.011$

remove 60% ⇒ 60% present in sludge

$V_{sl} = \frac{M_s}{S_{sl}\rho_w P_s}$

$= \frac{12000\times1000\times200\times10^{-6}\times0.6}{1.011(1000)(0.05)}$

$= \frac{1440}{1.011(1000)(0.05)}$

= 28.5 m³/d //

A'ZONE

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d) Acid rain is form by the presence of SO_2 in the atmosphere, where SO_2 will react with the water droplets in the atmosphere & O_2 to form sulphuric acid, which fall as acid rain.

$$SO_2 + H_2O + O_2 \rightarrow 2H_2SO_4$$

The negative impacts of acid rain on the environment are injury to vegetation, cause metal corrosion, water pollution, and attack on building material.

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$$