

ThOD =  $240 \text{ g } O_2 / 78 \text{ g } C_6H_6$   
 =  $3.08 \text{ g } O_2 / \text{g glucose } C_6H_6$

conc of  $C_6H_6 = 117 \text{ mg/L}$ ,  
 ThOD =  $3.08 \times 117 \text{ mg/L}$   
 =  $360 \text{ mg/L}$

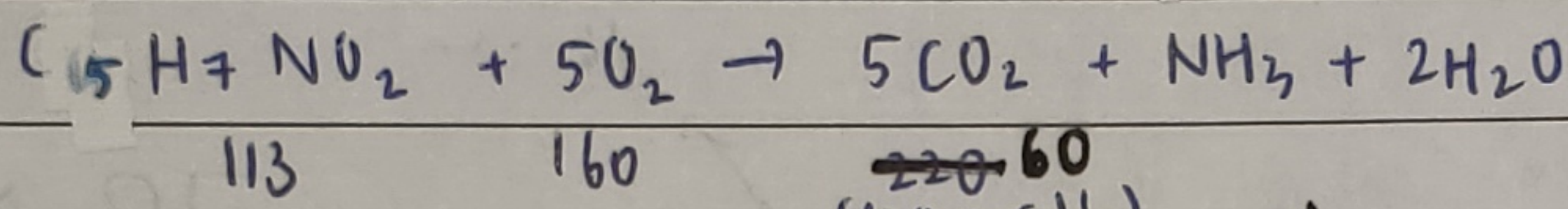
WW	Flowrate	BOD	COD
A	100 L/min	200 mg/L = 20000 mg/min	360 mg/L = 36000 mg/min
B	X	96 mg/L = 96x mg/min	320 mg/L = 320x mg/min
100 + X			

Since COD = ThOD

$BOD_5 / COD = 200 / 360 = 0.56 (> 0.5) \Rightarrow$  Good Treatability

Mix WW  
 average BOD =  $\frac{20000 + 96x}{100 + x}$   
 average COD =  $\frac{36000 + 320x}{100 + x}$

For WWB  $\rightarrow BOD_5 / COD = 0.3$



$C_5H_7NO_2 \rightarrow \frac{113}{120} \times 120 = 113 \text{ mg/L}$

ThOD =  $160 / 113 = 1.416 \text{ g } O_2 / \text{g } C_5H_7NO_2$   
 =  $1.416 \times 113 = 160 \text{ mg/L}$

$BOD_5 = 0.3 \times 160 = 48 \text{ mg/L} \rightarrow BOD / COD = 0.3$

$BOD / COD = 0.5$   
 $\frac{20000 + 96x}{36000 + 320x} = 0.5$   
 $20000 + 96x = 18000 + 160x$   
 $2000 = 64x$   
 $x = 31.25 \text{ L/min}$

$[ 200 (\frac{A}{A+B}) + 48 (\frac{B}{A+B}) ] / [ 360 (\frac{A}{A+B}) + 160 (\frac{B}{A+B}) ] = 0.5$   
 $200 (\frac{100}{100+B}) + 48 (\frac{B}{100+B}) = 180 (\frac{100}{100+B}) + 160 (\frac{B}{100+B})$   
 $20000 + 48B = 18000 + 160B$   
 $2000 = 112B$   
 $B = 17.86 \text{ L/min}$

~~1b) Sedimentation~~

~~21~~

a) Physical  $\rightarrow$  protect WWTP, remove debris, grit, oily scum, avoid shock loadings

$\rightarrow$  Screening (coarse, micro, fine) - remove SS

$\rightarrow$  Grit removal (sand, stones, inorganic particles), protect pump & equipment from abrasion, avoid clogging of pipes & channels

high specific gravity

$\rightarrow$  Primary sedimentation  $\rightarrow$  uses settling theory, remove SS that readily settle down, remove BOD

$\rightarrow$  Flotation (Dispersed air, DAF)  $\rightarrow$  introduce fine gas bubbles to attach to particulate matter & raised by buoyant force, target  $\rightarrow$  FOGs (low density than liquid)

Chemical  $\rightarrow$  coagulation & flocculation (destabilise particles so they aggregate, form larger mass, easier to remove from water  $\rightarrow$  remove turbidity.

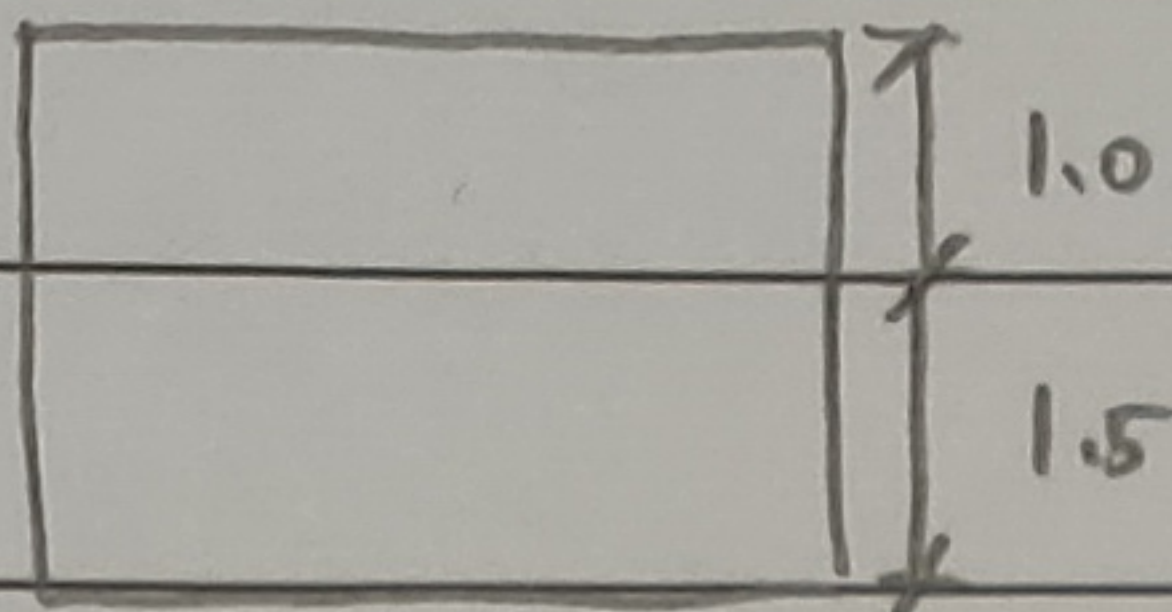
$\rightarrow$  Precipitation, remove TSS, P and heavy metals  $\rightarrow$  convert undesirable soluble substance into insoluble precipitate which can be removed easily.

$$m^3/m^2 \cdot d$$

$$\div (24 \times 3600)$$

19/20

2) a)



filtration rate = 0.0005 m/s

Bottom layer  $\rightarrow$  Material A

(B)  $d = 1.0 \text{ mm}$   
 $SG = 2.5$

$$\frac{d_2}{d_1} = \left( \frac{S_1 - 1}{S_2 - 1} \right)^{2/3}$$

$$d_B = d_A \left( \frac{S_A - 1}{S_B - 1} \right)^{2/3}$$

$$= 1.0 \left( \frac{2.5 - 1}{3.5 - 1} \right)^{2/3}$$

$$= 0.71$$

(C)

$$\frac{d_c}{d_A} = \left( \frac{S_A - 1}{S_C - 1} \right)^{2/3}$$

$$d_c = 1.0 \left( \frac{2.5 - 1}{2.0 - 1} \right)^{2/3}$$

$$= 1.31$$

(D)

$$\frac{d_D}{d_A} = \left( \frac{S_A - 1}{S_D - 1} \right)^{2/3}$$

$$d_D = 1.0 \left( \frac{2.5 - 1}{1.5 - 1} \right)^{2/3}$$

$$d_D = 2.1$$

$\star \rightarrow$

All are compatible in terms of having same settling velocity.

However, for the layer above, a material with lower SG should be chosen so that it can stay above the bottom layer made of Material A, hence material B is not chosen.

coarser material should also be used in the top layer, that is having larger size and porosity. Hence material D is chosen as  $d_D = 2.1 > 1.0$  and  $f_D = 0.45 > 0.4$

$\downarrow$   
So that top layer traps larger floc & bottom layer traps smaller floc (depth filtration)

$\star \rightarrow$

b) The advantages of using MF compare to granular media filtration for turbidity removal is that MF is more effective for removing protozoa than granular filtration which requires coagulation - flocculation step. It also has a higher packing density & hence smaller footprint compare to granular filtration.

Two disadvantages of MF compared to granular filtration is that MF is prone to membrane fouling which decrease permeate flux. Expensive cleaning and regeneration scheme is needed to be employed. Also, MF is ~~more exp~~ uses a more expensive equipment compare to granular media filtration (cost more than granular filtration)

low Ct  $\rightarrow$  low dosage & contact time

the lowest

c) i) For primary disinfection, ozone with  $C \cdot t$  value of 0.005 shows that it is a strong disinfectant, and ~~thus~~ besides, it does not react ~~with~~ and form THMs. However ozone may react with bromide ions to form harmful bromate ions and the production of  $O_3$  is very energy intensive. Both Free chlorine and chlorine dioxide ~~have~~ also have low  $C \cdot t$  value of 0.2. Chlorine dioxide is a good choice too but it ~~cost~~ more than chlorination and its health effects are not well established. Free chlorine is more cost effective and more commonly used. Free chlorine may be more suitable as the primary disinfectant. (But react to form trihalomethanes)

For secondary disinfectant, chloramine is chosen as it is very stable in water and is able to maintain a disinfectant residual in treated water distribution system, preventing biological growth in water pipes.

ii) Breakpoint = 0.8 mg/L  
Chlorine demand = 0.3 mg/L

Chlorine dosage = Chlorine Demand + Chlorine Residue at breakpoint,

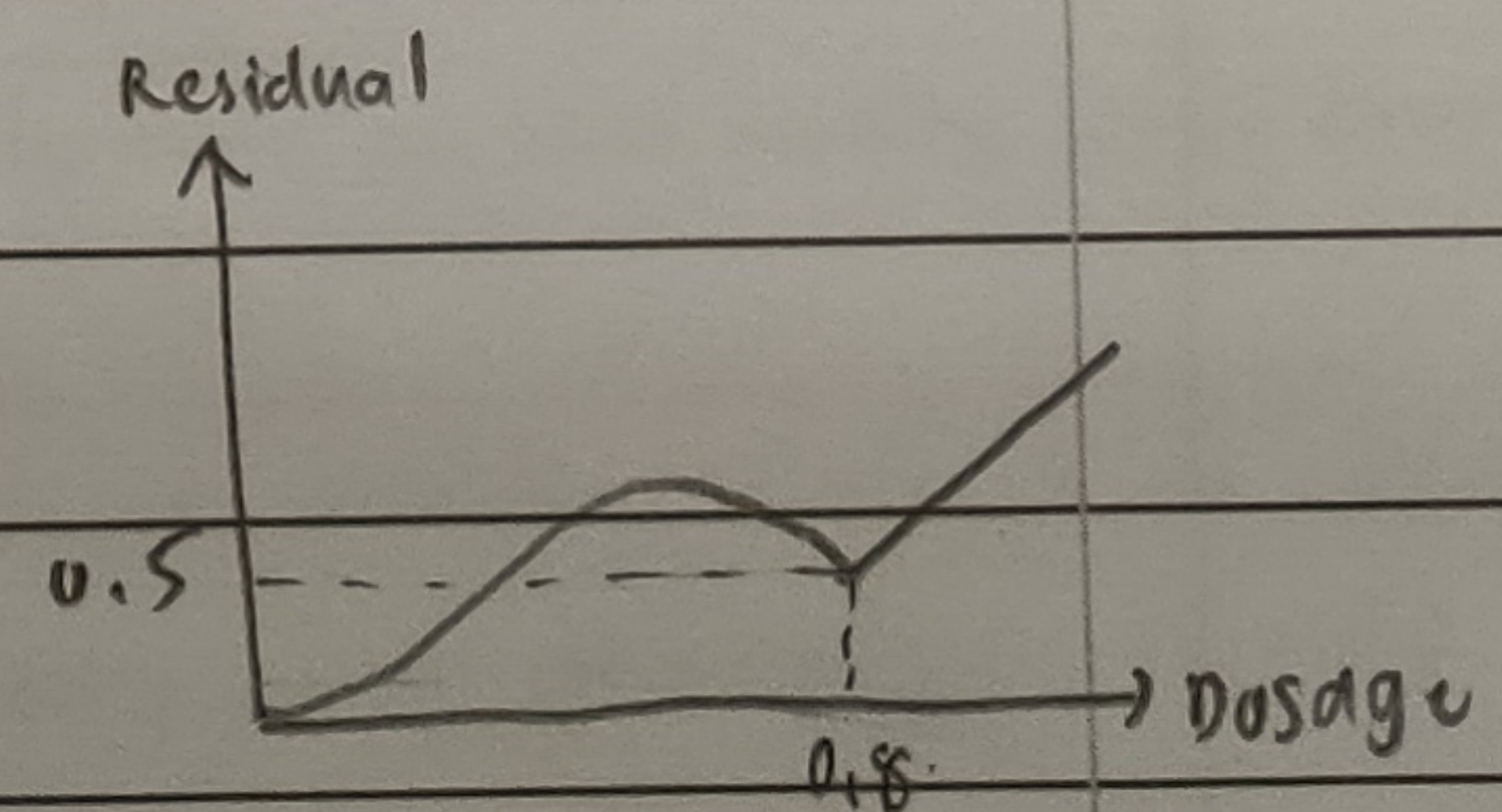
$$0.8 = 0.5 + \text{Chlorine Residual}$$

$$\text{Residual} = 0.3$$

at dosage of 1.5 mg/L

after breakpoint, all ~~residual~~ chlorine added will form free residual,

$$\text{Chlorine Residual} = 0.3 + (1.5 - 0.8) = 1.0 \text{ mg/L} //$$



$$\frac{\text{mg}}{\text{L}} \div 1000 = \frac{\text{g}}{\text{m}^3}$$

Date metals No.

→ Chemical oxidation (removing recalcitrant organic matters, reducing matters), improve treatability, eliminate inhibitory effects of certain compounds <sup>to microbes' growth</sup> reduce toxicity BOD, COD, Biological → suspended growth / attached growth → removal of BOD organics

$$1.5 - 1$$

$$2 - 2$$

3) b) In 1 mole of alum,  $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$  there's 2 moles of Al  
 1.5 mole of Al required for 1 mole of P  
 1 mole of Alum  $\frac{1}{1.5} = 1.27$  mole of P  
 666.5 g Alum  $\frac{1}{1.5} = 41.901$  g P  
 16 : 1

Amount of P per day =  $10 \text{ mg P/L} \times 10,000 \times 10^{-3}$   
 $= 100 \text{ kg/d}$

$[V (\text{L/d}) \times 1.2 \text{ kg/L} \times 50\%] \times 16 = 100 \times \frac{666.5}{41.901}$   
 $V \times 0.6 = 1618.11$   
 $V = 2696.85 \text{ Kg/d}$

For 30 d, storage capacity =  $2696.85 \times 30 = 80.91 \text{ m}^3$  ||  $= 1600 \text{ Kg/d}$   
 $= 2666 \text{ m}^3/\text{d}$

c)  $b_s \text{ COD}_{in} = 400 \text{ mg/L}$   
 $b_s \text{ COD}_e = 10 \text{ mg/L}$   
 $Q = 2000 \text{ m}^3/\text{d}$ ,  $\text{VSS} = 100 \text{ mg/L}$

observed yield =  $\frac{100 \text{ mg/L}}{1000} \times 2000 \text{ m}^3/\text{d}$   
 $= 200,000 \text{ g VSS/d}$

COD removed =  $(400 - 10) \text{ mg/L} \times 2000 \text{ m}^3/\text{d}$   
 $= 780,000 \text{ g COD/d}$

Observed biomass yield =  $\frac{200,000 \text{ g VSS/d}}{780,000 \text{ g COD/d}}$   
 $= 0.26 \text{ g VSS/g COD removed}$  ||

d)  $\text{SVI} = \frac{500 \text{ mL/L}}{3000 \text{ mg/L}} \times 1000 = 166.67 > 150$  (Poor settling, associated with filamentous growth)

effluent NH<sub>4</sub>-N

Date

No.

4) i)  $SRT = 1/\mu_n$

$$\mu_n = \left( \frac{\mu_{n,mN}}{K_n + N} \right) \left( \frac{DO}{K_o + DO} \right) - k_{dn}$$

$$= \left( \frac{0.75(0.5)}{0.74 + 0.5} \right) \left( \frac{2}{0.5 + 2} \right) - 0.08$$

$$= 0.16 \text{ g/g.d}$$

Theoretical

$$SRT = 1/\mu_n = 1/0.16 = 6.25 \text{ d}$$

$$\text{Design } SRT = 1.6 \times 6.25 \text{ d} = 10 \text{ d} \parallel$$

ii)  $NO_x = TKN - N_e - 0.12 P_{x, N} / Q$

$$= 35 \text{ g/m}^3 - 0.5 \text{ g/m}^3 - 0.12 (1000) (10 \text{ d}) / 20,000 \text{ m}^3/\text{d}$$

$$= 28.5 \text{ g/m}^3 \quad \text{1g VSS}$$

$N_{\text{natural}} + N_{\text{added}}$

$$= N_{\text{consumed}} + N_{\text{final}}$$

$$140 + N_{\text{added}} = 203.5 + 80$$

$$\text{ALK used for nitrification} = (7.14) (28.5) = 203.5 \text{ g/m}^3 \text{ as CaCO}_3$$

To maintain pH, residual alkalinity required is 80 mg/L / 80 g/m<sup>3</sup> as CaCO<sub>3</sub>.

$$80 \text{ g/m}^3 = 140 - 203.5 + \text{ALK to be added}$$

$$\text{ALK to be added} = 143.5 \text{ g/m}^3$$

$$\text{Mass} = 143.5 \text{ g/m}^3 \times 20000 \text{ m}^3/\text{d} = 2869.8 \text{ kg/d as CaCO}_3 \leftarrow$$

which it is return to system that produce 2 types of sludge

b) Two sludge → nitrification & denitrification  
post-anoxic denitrification with external carbon source

① Nitrification (aerobic) - O<sub>2</sub> → return biomass

+ methanol (org compound, electron donor)

denitrification tank → return biomass

sludge ← secondary clarifier → effluent sCOD or COD

$$V_n = \frac{Q S_0}{L_{org}}$$

$$= \frac{1000 \text{ m}^3/\text{d} \times 2300 \text{ g/m}^3}{10 \text{ kg sCOD/m}^3 \cdot \text{d}}$$

$$= 230 \text{ m}^3 \parallel$$

$$V_n = \frac{Q S_0}{L_{org}} = \frac{1000 \times 2000}{10 \text{ kg}} = 200 \text{ m}^3$$

$$V_L = \frac{200}{0.85} = 235 \text{ m}^3$$

$$V_L = \frac{V_n}{E} = \frac{230}{0.85} = 270.6 \text{ m}^3$$

$$HRT = \frac{V}{Q} = \frac{270.6}{1000} = 0.271 \text{ d} = 6.5 \text{ hrs} \parallel$$

$$HRT = \frac{V}{Q} = \frac{235}{1000} = 0.235 \text{ d} = 5.64 \text{ hrs}$$

$V_n$  - effective volume.

(Vol. that have biomass that can remove things)

$V_L$  - liquid.

(COD includes all soluble & particulate COD)

d) Impacts of SO<sub>x</sub> are such as formation of acid rain which damage our environment such as injury of vegetation & corrosion of metal. Acid rain is form ~~acid~~ when SO<sub>2</sub> reacts with O<sub>2</sub> & H<sub>2</sub>O in atmosphere to form H<sub>2</sub>SO<sub>4</sub>. SO<sub>x</sub> also causes formation of sulphurous ~~to~~ smog that reduces visibility. Finally, SO<sub>x</sub> emission causes attacks on building materials such as Marble structures when H<sub>2</sub>SO<sub>4</sub> react with CaCO<sub>3</sub> to form partially water soluble CaSO<sub>4</sub> that can be washed away.

To reduce SO<sub>x</sub> emission, reduce the usage of sulphur containing fuel such as coal or oil. Instead source for alternative clean energy sources to generate energy.