Subject: CV 3501 No: Date:

2012|2013 sem I Env. Engg

1a) (i) (25000 m^3/d ÷ 500 000 people) × 1000 = 500 Lpcd

(ii) Arithmetic rate → Assuming population grows linearly

Annual growth rate → (80 000 − 50 000) / 20 = 1500 people / year

No. of people to fully utilize design capacity → 37000 m^3/d ÷ 500 Lpcd)

= 74000 people

↳ we assume that the per capita water consumption remains the same

since $P_t = P_o + K_u t$

$74000 = 50\,000 + 1500t$

$t = 16$ years

(iii) Yes. we can reduce water demand by implementing a water conservation programme by installing dual-flush cisterns, water trimble and reducing ~~leaking~~ leakage in pipes and fittings

1b) 24 hr Pumping Rate : Pumping → (26400 ÷ ~~12~~ 24 hrs) × 2 = 2200 m^3

Time	Demand (m^3)	Pumping	Excess Pumping	Excess Demand
12-2am	610	2200 m^3	1590	
2-4am	600		1600	
4-6am	650		1550	
6-8am	1350		850	
8-10am	2500			300
10-12pm	2750			550
12-2pm	2950			750
2-4pm	3250			1050
4-6pm	3000			800
6-8pm	3800			1600
8-10pm	3590			1390
10-12am	1350		850	
	26400		6440 m^3	6440 m^3 → Both same (check).

Equalising storage → 6440 m^3

bii) minimum:

maximum. 4am (

Equalising storage at 6pm → 800 m^3

(iii) 12 - 8pm. That's when the demand for water is the highest

2a)

(i)

component	concentration (mg/L)	Eqv. wt. (mg/meq)	conc. (meq/L)
Ca^{2+}	94	20	94/20 = 4.7
Mg^{2+}	24	12.2	24/12.2 = 1.96
Na^+	14	23	14/23 = 0.61
SO_4^{2-}	67	48	1.395
Cl^-	24	35.5	0.676

Total cation (+) = 7.27 = 4.7 + 1.96 + 0.61

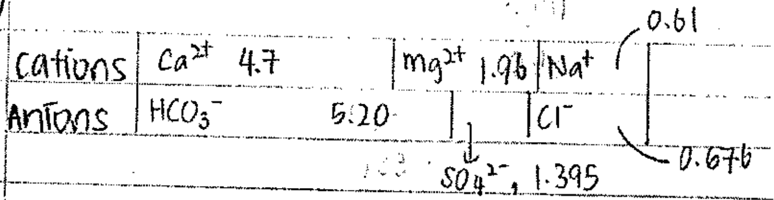
Total Anion (−) = 1.395 + 0.676 = 2.071 meq/L

It's incomplete as Σ Anion ≠ Σ cation

(ii) concentration (meq/L) → 7.27 − 2.071 = 5.20 meq/L

concentration (mg/L) → 5.20 meq/L × 61 mg/meq = 317.2 mg/L

(iii)



Hypothetical combinations

$Ca(HCO_3)_2$ = 4.7 meq/L ✓

Mg ~~(HC~~ $HCO_3)_2$ = 0.504 meq/L ✓

NaCl = 0.61 meq/L

$MgSO_4$ = 1.395 meq/L

$MgCl_2$ = 0.065 meq/L

(iv) carbonate Hardness → 5.20 meq/L × 50 mg/meq = 260 mg/L as $CaCO_3$

Total Hardness → (4.7 + 1.96 meq/L) × 50 mg/meq = 333 mg/L as $CaCO_3$

Non-carbonate → 333 − 260 mg/L as $CaCO_3$ = 73 mg/L as $CaCO_3$

2bi) vol. of tank → $10 \times 3 \times 3 = 90m^3$

$Q = 4500 m^3/d$

(i) Total power → $G^2 \mu V = P$

$P = (40)^2 (0.89 \times 10^{-3})(90) = 128.16 W$

(ii) $N = 5rpm = 5/60 \, rps = 0.0833 \, rps$

$V_p = 2\pi r N = 2\pi(1)(0.0833 \, rps) = 0.524 \, m/s$ (For one paddle blade)

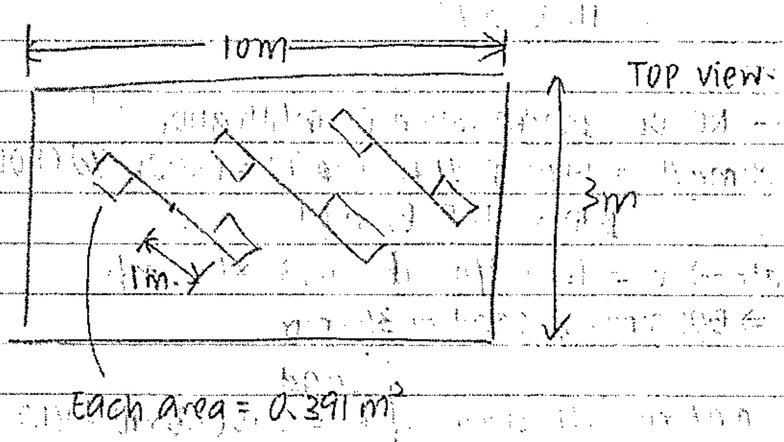
$P = 0.5 C_D A \rho v^3$ where $v = 0.75 V_p$

$128.16 = 0.5(1.8)A(1000)(0.75(0.524))^3$

$A = 2.346 m^2$ (Total Area)

Area of one paddle → 2.346 ÷ (3 paddle wheel x 2 paddle blade)

$= 0.391 m^2$



biii) HRT → $V/Q = 90\,m^3 / 4500\,m^3/d = 28.8\,min.$

Significance of.

① Hydraulic detention time → How long water stays in tank

② mean velocity gradient → Degree of mixing

Together, they determine the total number of particle collision

3ai) combined water → $400\,ha \times 60\,people/ha \times 0.320\,m^3pcd = 7680\,m^3/d$

$$+$$

$$5\,m^3/ha.d \times 400\,ha = 2000\,m^3/d$$

$$+$$

$$80/1000\,m^3pcd \times 60\,people/ha \times 400\,ha = 1920\,m^3/d$$

$$= 11600\,m^3/d$$

aii) combined BOD

Assumption → NO BOD concentration in infiltration

$7680\,m^3/d(250\,mg/L) + 1920\,m^3/d(200\,mg/L) = 11600\,m^3/d\,(BOD)$

$$BOD = 198.62\,mg/L$$

(b) Filtration rate → $v = 150\,m^3/m^2 \cdot d = 1.736 \times 10^{-3}\,m/s$

(i) Anthracite ⇒ 500mm. , sand ⇒ 300mm.

Anthracite

$$Re = \frac{\psi d V}{\nu} = \frac{0.9(1\times10^{-3})(1.736\times10^{-3})}{1 \times10^{-6}}$$

$$= 1.5624$$

$$C_D = \frac{24}{1.5624} + \frac{3}{\sqrt{1.5624}} + 0.34 = 18.11$$

$$\frac{h}{0.5m} = \frac{1.067(18.11)(1.736\times10^{-3})^2}{0.9(9.81)(1\times10^{-3})(0.45)^4}$$

$$= 80.42\,mm.$$

sand

$$Re = \frac{0.75(0.5\times10^{-3})(1.736\times10^{-3})}{1 \times10^{-6}}$$

$$= 0.651$$

$$C_D = \frac{24}{0.651} = 36.86$$

$$\frac{h}{0.3} = \frac{1.067(36.86)(1.736 \times 10^{-3})^2}{0.75(9.81)(0.5\times10^{-3})(0.40)^4}$$

$$= 377.6\,mm.$$

Total Head loss → $377.6 + 80.42 = 458.02\,mm$

(ii) Weighted f → $0.45(500) + 0.4(300) = f_w(800)$

$$f_w = 0.43$$

$$1.4 = \frac{1-0.43}{1-f_e} \quad ; \quad f_e = 0.592$$

$V_b = 0.12(0.592)^{4.5}$ ~~= 0.011 m/s~~

(iii) d_2 = Anthracite

$$\therefore d_2 = 0.5\times10^{-3}\left(\frac{2.65-1}{1.55-1}\right)^{2/3} = 1.04\times10^{-3}\,m = 1.04mm > 1mm$$

∴ No intermixing

(c) $Q = 90000\ m^3/d$

Q for 1 tank → $90\ 000 m^3/d \div 4 = 22500 m^3/d$

$V/Q = 3hr \rightarrow V/22500 m^3/d \times 24 = 3$

$V = 2812.5 m^3$.

let width = w

∴ Area = $2.5 w^2$

Q/A = overflow rate → $22500\ m^3/d \div 25w^2\ m^2 = 35 m^3/m^2 \cdot d$

$w = 16m$.

$l = 16 \times 2.5 = 40m$.

Depth → $2812.5\ m^3 \div (16 \times 40\ m^2) = 4.39m \simeq 4.4\ m$

4a)

Domestic WW → Primary treatment → secondary treatment $V = 3000m^3$

BOD = 300mg/L BOD = 195mg/L

SS = 300mg/L SS = 90mg/L

(i) Aeration → $V/Q = 3000\ m^3 \div (10\ 000 m^3/d) \times 24hrs/d = 7.2hrs$.

(ii) F/m ratio → $\frac{Q.S_0}{VX} = \frac{10000\ m^3/d\,(195mg/L)}{3000m^3(3000mg/L)(0.8)} = 0.27$

(iii) $VLR = \frac{Q.S_0}{V} = \frac{10\ 000m^3/d\,(195\,mg/L)}{3000\ m^3} = 0.65\ kg/m^3 \cdot d$

(iv) mean cell residence time → $\frac{VrX}{Q_eX_e + Q_wX_r}$ since $X_e = 0$ ∴

$$\theta_c = \frac{3000m^3(3000\,mg/L)(0.8)}{100m^3/d\,(1\% \times 10^6 mg/L)(0.8)} = 9\ days.$$

(v) $\frac{Q_r}{Q} = \frac{X}{X_r - X}$, $Q_r = \frac{(10\,000)(3000)(0.8)}{(10\,000\quad 1) - (3000)(0.8)} = 3157.9\ m^3/d$

4b) Primary sludge → Solids + water

5% + 95% = 100%

(Primary) solids → Volatile + Fixed

60% + 40% = 100%

$\frac{W_s}{\rho_s} = \frac{W_f}{\rho_f} + \frac{W_v}{\rho_v}$ $\rho_v = 1.0$

$\rho_f = 2.8$

$\frac{1}{\rho_s} = \frac{0.4}{2.8} + \frac{0.6}{1.0}$

$\rho_s = 1.34$

$\frac{W_{s1}}{\rho_{s1}} = \frac{W_w}{\rho_w} + \frac{W_s}{\rho_s}$

$\frac{1}{\rho_{s1}} = \frac{0.95}{1} + \frac{0.05}{1.34}$

$\rho_{s1} = 1.01$

Wasted Activated sludge → Solids + water

1% + 99% = 100%

wasted (solids) → volatile + Fixed

80% + 20% = 100%

$\frac{W_s}{\rho_s} = \frac{W_f}{\rho_f} + \frac{W_v}{\rho_v}$

$\frac{1}{\rho_s} = \frac{0.2}{2.8} + \frac{0.8}{1.0}$, $\rho_s = 1.15$

$\frac{1}{\rho_{s1}} = \frac{W_w}{\rho_w} + \frac{W_s}{\rho_s}$

$\frac{1}{\rho_{s1}} = \frac{0.99}{1} + \frac{0.01}{1.15}$, $\rho_{s1} = 1.00$

Vol. of pri sludge → $\frac{(10000 m^3/d \times 300 mg/L \times 0.6)}{1.01(0.05)} = 35643 m^3$

Vol. of wasted sludge → $\frac{10 000 mg/L \times 100 m^3/d}{1(0.01)} = 10000 m^3$

Total sludge vol. → 35643 + 10 000 = 45643 m^3 daily

4c) This is a design question. ∴ the answers you get might not necessarily be the same as mine as we might make different assumptions. (But the steps are rather similar).

effluent BOD (using mass balance)

↳ 20000 m³/d (3 mg/L) + 5000 m³/d (Eff. BOD) = 25000 m³/d (10 mg/L)

Effleent BOD → 38 mg/L

BOD after primary treatment

↳ 400 mg/L × (100% − 35%) = 260 mg/L. = S_0

Treatment efficiency by trickling filter → $\frac{260-38}{260}$ = 85.4%.

using NRC eqn

$$W = \frac{Q.S_0}{V} = \frac{20000\,m^3/d\,(260\,mg/L)}{V} = \frac{5200}{V}\ kg\,BOD/d.$$

Assume recirculation ratio, $R = 2 \rightarrow \frac{Q_r}{Q} = 2$, $Q_r = 2Q$.

$$F = \frac{1+2}{(1+0.1(R))^2} = 2.08$$

$$85.4 = \frac{100}{1+0.448\sqrt{\frac{5200}{V^2(2.08)}}}\ ,\ \frac{5200}{2.08V^2} = 0.1456\ ,\ V = 131.02\ m^3$$

Hydraulic loading rate → $(Q+Q_r)/A_s$ Organic loading rate → $Q(BOD)/V$

Assuming tank is circular → $\frac{\pi d^2}{4}$ × depth = 131.02 m³ (Assume tank is 2m deep).

d = 9.13 m (diameter)

Hydraulic loading rate → $(Q+2Q)/((131.02/2)\,m^2) = \frac{3(20000\,m^3/d)}{65.51\,m^2}$

$= 915.89\ m^3/m^2 \cdot d$

organic loading rate → $\frac{20000\,m^3/d\,(260\,mg/L)}{131.02\,m^3} = 39.68\,kg/m^3 \cdot d$