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EN3002

22-23_S1

Q1(a)(i)

$$\text{COD } C_2H_6O_2 = \frac{2.5 \times 32}{12 \times 2 + 6 + 16 \times 2} = 1.29 \text{ g } o_2 / \text{ g } C_2H_6O_2 \text{ g}$$

$$\text{COD } C_6H_6O = \frac{7 \times 32}{12 \times 6 + 6 + 16} = 2.38 \text{ g } o_2 / \text{ g } C_6H_6O$$

$$\text{COD } C_6H_{12}O_6 = \frac{6 \times 32}{12 \times 6 + 12 + 16 \times 6} = 1.07 \text{ g } o_2 / \text{ g } C_6H_6O_2$$

In wastewater,

$$\text{COD} = 150 \times 1.29 + 2.38 \times 100 + M \times 1.07 = 596$$

$$\mathbf{M = 153.7 \text{ mg/L}}$$

Q1(a)(ii)

$$\text{TOC } C_2H_6O_2 = \frac{12 \times 2}{12 \times 2 + 6 + 16 \times 2} = 0.387 \text{ g } C / \text{ g } C_2H_6O_2 \text{ g}$$

$$\text{TOC } C_6H_6O = \frac{12 \times 6}{12 \times 6 + 6 + 16} = 0.766 \text{ g } C / \text{ g } C_6H_6O$$

$$\text{TOC } C_6H_{12}O_6 = \frac{12 \times 6}{12 \times 6 + 12 + 16 \times 6} = 0.4 \text{ g } C / \text{ g } C_6H_6O_2$$

In wastewater,

$$\text{TOC} = 150 \times 0.387 + 100 \times 0.766 + 153.7 \times 0.4 = 196.1 \text{ mg/L}$$

Q1(b)(i)

$$\text{10-day BOD} = \frac{300 \times (7.5 - 1.5)}{3} = 600 \text{ mg/L}$$

From given equation,

2 mols of NO_3 requires 4 mols of O_2 to form

No. of mols of $\text{NO}_3 = 0.6/14 = 0.04286 \text{ mMol/L}$

No. of mols of $\text{O}_2 = 0.04286 \times 2 = 0.0857 \text{ mMol/L}$

$$\text{Nitrogenous BOD} = \frac{300 \times 0.0857 \times 32}{3} = 274 \text{ mg/L}$$

$$\text{Carbonaceous BOD} = 600 - 274 = 326 \text{ mg/L}$$

Q1(b)(ii)

$$\text{20-day BOD} = \frac{300 \times 7.5}{3} = 750 \text{ mg/L}$$

All the O_2 present is used up for oxidation by microbes, thus further oxidation cannot occur even if more biodegradable organics are present, thus BOD is just determined by the total amount of oxygen present.

Q1(c)

Carry-out evaporation of sample at 105°C , the mass of residue will be the mass of total solids.

Measure the change in mass of total solids after burning at 500°C .

This decrease in mass = mass of TVS

Q2(a)(i)

$$V_o = \frac{Q}{A} = \frac{30000}{40 \times 10} = 75 \text{ m/d} = 0.0008681 \text{ m/s}$$

$$V_s = \frac{9.81(1.03-1)(100 \times 10^{-6})^2}{18(1.003 \times 10^{-6})} = 0.000163 \text{ m/s} < V_o$$

Not completely removed

Q2(a)(ii)

Increased temperature leads to decreased viscosity, and thus increased settling velocity, improving performance and efficiency of sedimentation basin.

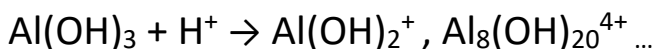
Q2(b)

At optimal pH :



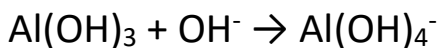
Al^{3+} is present to neutralize negative charge, $\text{Al}(\text{OH})_3$ precipitates formed improve coagulation by capturing particles as they settle

At too low a pH :



Positive complexes are formed instead, charge neutralization can still occur but no formation of precipitates

At too high a pH :



Negative complexes form, no charge neutralisation and no formation of precipitates

Q2(c)(i)

$$\text{No. of mol of } PO_4^{3-} = \frac{10 \times 10^{-3}}{31} = 0.000323 \text{ mol/L}$$

$$\text{No. of mol of } Ca^{2+} = \frac{20 \times 10^{-3}}{40} = 0.0005 \text{ mol/L}$$

$$0.005 \text{ mol / L } Ca^{2+} \text{ removes } \frac{6}{10} \times 0.005 = 0.0003 \text{ mol/L } PO_4^{3-}$$

$$\text{Removal efficiency} = \frac{0.0003}{0.000323} \times 100\% = 93\%$$

Q2(c)(ii)

$$\text{No. of mol of } Ca_{10}(PO_4)_6(OH)_2 = 0.0005 / 10 = 0.00005 \text{ mol/L}$$

$$\text{Atomic mass of } Ca_{10}(PO_4)_6(OH)_2 = 40 \times 10 + 95 \times 6 + 17 \times 2 = 1004$$

$$\text{Mass solids} = 0.00005 \times 1004 \times 10000 \times 10^3 = 502000 \text{ g/d} = 502 \text{ Kg/d}$$

Q2(d)

$$Q_1 C_1 + Q_2 C_2 = Q_3 C_3 + Q_{\text{permeate}} C_{\text{Permeate}}$$

$$C_{\text{Permeate}} = \frac{Q_1 C_1 + Q_2 C_2 - Q_3 C_3}{Q_{\text{Permeate}}} = \frac{Q_1 C_1 + Q_2 C_2 - Q_3 C_3}{Q_1 + Q_2 - Q_3}$$

Q3(a)

- i. Increasing SRT increases contact time of microorganisms with wastewater, allowing for growth of more biomass and higher P uptake, decreasing effluent P concentration
- ii. Readily biodegradable COD increase, VFA in influent increase, more PHA formed during anaerobic process, more PHA converted to CO_2 during aerobic process to release energy, more energy to take in P in wastewater from wastewater to form poly-P, higher P uptake and thus lower P concentration in effluent
- iii. Increase in suspended solid concentration leads to accumulation of inert solids in reactor, and increased discharged of active biomass from the system, reduce the amount of active biomass in the system, and thus reducing P intake, increase P concentration in effluent
- iv. Nitrate can act as electron acceptor during anaerobic stage, competing with PHA formation. Less PHA will be formed. During aerobic stage, less PHA is available for conversion to CO_2 to release energy, less energy for P uptake to form poly-P, less P uptake occurs and thus P concentration in effluent increases

Q3(b)

	Aerobic	Fermentation	Methanogenesis
End products	CO ₂ , H ₂ O, biomass	H ₂ , CO ₂ , biomass	CH ₄ , CO ₂ biomass
Yield	Highest	moderate	Lowest

Q3(c)

$$\text{COD consumed} = 5000 \times 0.95 = 4750 \text{ mg/L}$$

$$\text{Net biomass produced} = 4750 \times 0.04 = 190 \text{ mg/L}$$

$$\text{COD biomass} = 190 \times 1.42 = 269.8 \text{ mg/L}$$

$$\text{COD methane} = 4750 - 269.8 = 4480.2 \text{ mg/L} = 4480.2 \text{ g/m}^3$$

$$\text{COD methane} = 4480.2 \times 3000 = 13440600 \text{ g/d}$$

$$\text{Vol methane} = 13440600 \times 0.4 = 5376240 \text{ L/d} = 5376 \text{ m}^3/\text{d}$$

Q3(d)

$$S_0 = 300 \text{ mg/L} \quad S = 15 \text{ mg/L} \quad V = 105 \text{ m}^3$$

$$nbVSS = 50 \text{ mg/L} \quad X = 2000 \text{ mg/L} \quad f_d = 0.1$$

$$r_{su} = -\frac{kXS}{S+K_s} = -\frac{5(2000)(15)}{15+40} = -2727 \frac{\text{mg}}{\text{L.d}}$$

$$r_g = -Yr_{su} - K_dX = -(0.4)(-2727) - (0.1)(2000) = 890.8 \frac{\text{mg}}{\text{L.d}}$$

$$\text{Net biomass growth} = 890.8 \times 105 \times 10^3 = 93534000 \text{ mg/d}$$

$$\text{Net yield} = \frac{93534000}{1000 \times 10^3 (300 - 15)} = 0.33 \text{ g VSS/g bsCOD}$$

$$\begin{aligned}
 r_{X_T, VSS} &= -Yr_{su} - K_d X + f_d(K_d)X + \frac{QX_{o,i}}{V} \\
 &= 890.8 + 0.1 \times 0.1 \times 2000 + \frac{1000 \times 10^3 \times 50}{105 \times 10^3} \\
 &= 1387 \frac{mg}{L \cdot d}
 \end{aligned}$$

$$\text{Observed yield} = \frac{1387 \times 105 \times 10^3}{1000 \times 10^3 \times (300 - 15)} = 0.51 \text{ g VSS/ g bsCOD}$$

Q4(a)

$$\frac{M_S}{S_S} = \frac{M_V}{S_V} + \frac{M_f}{S_f} = \frac{0.75M_S}{1.3} + \frac{0.25M_S}{2.6}$$

$$\frac{M_S}{S_S} = \frac{35}{52} M_S$$

$$S_S = \frac{52}{35}$$

$$\frac{M_{Sl}}{S_{Sl}} = \frac{M_S}{S_S} + \frac{M_W}{S_W} = \frac{0.04M_{Sl}}{\left(\frac{52}{35}\right)} + \frac{0.96M_{Sl}}{1}$$

$$\frac{M_{Sl}}{S_{Sl}} = \frac{1283}{1300} M_{Sl}$$

$$S_{Sl} = 1.013$$

$$\rho_{Sl} = 1013 \text{ kg/m}^3$$

Sludge is 96% water, 4% solid

$$200 \text{ mg/L} = 200 \text{ g/m}^3$$

$$\text{S.S removed} = 200 \times 8000 = 1600000 \text{ g/d} = 1600 \text{ kg/d}$$

$$\text{Mass sludge} = \frac{1600}{0.04} = 40000 \text{ kg/d}$$

$$\text{Vol sludge} = \frac{40000}{1013} = 39.49 \text{ m}^3/\text{d}$$

$$\text{Vol digester} = 39.49 \times 20 = 789.8 \text{ m}^3$$

Q4(b)

$$R=2, \quad F = \frac{1+R}{\left(1+\frac{R}{10}\right)^2} = 2.08$$

$$W_1 = 5000 \times 220 \times 0.65 = 715000 \text{ g/d} = 715 \text{ kg/d}$$

$$\text{Removal efficiency} = 1 - \frac{20}{220 \times 0.65} = 0.86$$

$$p_1 \times p_2 = 1 - 0.86 = 0.14$$

$$p_1 = p_2 = 0.374$$

Efficiency of each filter = 0.626

$$E_1 = \frac{100}{1 + 0.4432 \sqrt{\frac{W_1}{FV_1}}}$$

$$62.6 = \frac{100}{1 + 0.4432 \sqrt{\frac{715}{2.08V_1}}}$$

$$\mathbf{V_1 = 189 \text{ m}^3}$$

$$h = 1.5 \text{ m}$$

$$V = \frac{\pi d^2}{4} \times h$$

$$\mathbf{d_1 = 12.67 \text{ m}}$$

$$W_2 = 715 \times (1 - 0.626) = 267.4 \text{ kg/d}$$

$$E_2 = \frac{100}{1 + \frac{0.4432}{1-E_1} \sqrt{\frac{W_2}{FV_2}}}$$

$$62.6 = \frac{100}{1 + \frac{0.4432}{1-0.626} \sqrt{\frac{267.4}{2.08V_2}}}$$

$$\mathbf{V_2 = 506 \text{ m}^3}$$

$$\mathbf{d_2 = 20.72 \text{ m}}$$