6.1 Activated Sludge Design

a) $[\theta_x^{min}]_{lim} = \dfrac{1}{Y\hat{q} - b}$, or $\underline{\mathbf{[\theta_x^{min}]_{lim} = 0.115\ day}}$

b) $\theta_x^{des} = [\theta_x^{min}]_{lim} * S.F. = 0.115 * 60 = \underline{\mathbf{6.9\ days}}$

c) $$S = K\frac{1 + b\theta_x}{Y\hat{q}\theta_x - (1 + b\theta_x)} = \underline{\mathbf{5.7\ mg/l}}$$

d) $$U = \frac{\hat{q}S}{K + S} = \underline{\mathbf{0.61\ kg/kg\ VSS\text{-}day}}$$

e) $$\frac{\Delta S}{\Delta t} = -Q(S^0 - S) = \underline{\mathbf{1{,}180\ kg/day\ removed}}$$

f) $$\frac{\Delta X_a}{\Delta t} = V\frac{dX_a}{dt} = -\frac{\Delta S}{\Delta t}\frac{Y}{1 + b\theta_x} = -Q(S^0 - S)\frac{Y}{1 + b\theta_x} = \underline{\mathbf{279\ kg\ VSS_a/day}}$$

$$\frac{\Delta X_i}{\Delta t} = V\frac{dX_i}{dt} = \frac{\Delta X_a}{\Delta t}(1 - f_d)b\theta_x = \underline{\mathbf{38.5\ kg\ VSS_i/day}}$$

$$\frac{\Delta X_v}{\Delta t} = \frac{\Delta X_a}{\Delta t} + \frac{\Delta X_i}{\Delta t} = \underline{\mathbf{318\ kg\ VSS_v/day}}$$

g) $$X_a V = \theta_x\left(\frac{\Delta X_a}{\Delta t}\right) = \underline{\mathbf{1925\ kg\ VSS_a}}$$

$$X_i V = \theta_x\left(\frac{\Delta X_i}{\Delta t}\right) = \underline{\mathbf{265\ kg\ VSS_i}}$$

$$X_v V = \theta_x\left(\frac{\Delta X_v}{\Delta t}\right) = \underline{\mathbf{2190\ kg\ VSS_v}}$$

h) $$V = \frac{X_v V}{X_v} = \underline{\mathbf{8.8\ x\ 10^2\ m^3}}.$$

$$\theta = \frac{V}{Q} = \underline{\mathbf{0.22\ days = 5.3\ hr}}.$$

i) $$\frac{X_a}{X_a + X_i} = \frac{X_a V}{X_a V + X_i V} = \frac{X_a V}{X_v V} = \underline{\mathbf{0.88}}$$

$X_a = 0.88 * X_v = \underline{\mathbf{2200\ mg/l}}$

j)

$$\frac{\Delta X_v}{\Delta t} = Q^w X_v^R + (Q - Q^w) X_v^e \text{, and}$$

$$Q^w = \frac{\frac{\Delta X_v}{\Delta t} - Q X_v^e}{X_v^R - X_v^e} \text{, where} X_v^R = X_a^R + X_i^R \text{, and } X_v^e = X_a^e + X_i^e$$

Q^w = **<u>23.8 m³/day</u>**

Since $\frac{X_a}{X_v} = 0.88, X_a^R = 0.88 * X_v^R = 8800$ mg VSS/l.

Also, $X_i^R = X_v^R - X_a^R = 1200$ mg VSS/l.

The kg/day that must be wasted will then be :

$Q^w X_v^R$ = **238 kg VSS/day**

$Q^w X_a^R$ = **209 kg VSS/day**

$Q^w X_i^R$ = **29 kg VSS/day**

k) $$R = \frac{Q^R}{Q} = \frac{X_v\left(1 - \theta/\theta_x\right)}{X_v^R - X_v}$$

or, R = **<u>0.323</u>**

$Q^R = RQ$ = **<u>1290 m³/day.</u>**

l) $$\text{V.L.} = \frac{QS^0}{V} \text{, or,}$$

V.L. = **<u>1.36 kg/m³-day</u>**

m)

$$X^e_{a(BOD_L)} = X_a^e \cdot 1.42 \frac{\text{mg BOD}_L}{\text{mg VSS}} \cdot f_d,$$

where, $X_a^e = 0.88 \cdot X_v^e$. Substituting, we get :

$X^e_{a(BOD_L)}$ = **20 mg/l**

n) The UAP and BAP constants are the following (Noguera et al., 1991):

$\hat{q}_{UAP} = 1.8$ mg COD_P / mg VSS - d
$\hat{q}_{BAP} = 0.1$ mg COD_P / mg VSS - d
$K_{UAP} = 100$ mg COD_P / l
$K_{BAP} = 85$ mg COD_P / l
$k_1 = 0.12$ g COD_P / g COD_S
$k_2 = 0.09$ g COD_P / g VSS - d

The equations for the calculations of UAP and BAP are the following:

$$\text{UAP}=\frac{-\left(\hat{q}_{UAP}X_a\theta+K_{UAP}+k_1r_{ut}\theta\right)+\sqrt{\left(\hat{q}_{UAP}X_a\theta+K_{UAP}+k_1r_{ut}\theta\right)^2-4K_{UAP}k_1r_{ut}\theta}}{2}$$

$$\text{BAP}=\frac{-\left(K_{BAP}+(\hat{q}_{BAP}-k_2)X_a\theta\right)+\sqrt{\left(K_{BAP}+(\hat{q}_{BAP}-k_2)X_a\theta\right)^2+4K_{BAP}k_2X_a\theta}}{2}$$

where, $r_{ut} = -\ \dfrac{S^0 - S}{\theta}$

Substituting in the above equations, we get the following results:

UAP = **3.8 mg/l**
BAP = **30.6 mg/l**
And, SMP = UAP + BAP = **34.4 mg/l**

Total Effluent $BOD_{L,soluble} = COD_{sol}$ = SMP + S = **40.1 mg/l**
Total Eff. $BOD_L = 40.1 + 20 = 60.1$ mg/l Total Eff COD = $40.1 + 1.42 \times 20 = 68.5$ mg/l

o)

$$\frac{\Delta N}{\Delta t}=\left(\frac{\Delta X_v}{\Delta t}\right)\gamma_N=\left(\frac{\Delta X_v}{\Delta t}\right)\cdot 0.124\,\frac{\text{kg N}}{\text{kg VSS}}=\mathbf{39\,\frac{kg\,N}{day}}$$

$$\frac{\Delta P}{\Delta t}=\cdot\frac{1}{5}\frac{\Delta N}{\Delta t}=\mathbf{7.9\,\frac{kg\,P}{day}}$$

$$N^0=\frac{\Delta N}{\Delta t}\frac{1}{Q}=\mathbf{9.8\ mg\ N/l}$$

$$P^0=\frac{\Delta P}{\Delta t}\frac{1}{Q}=\mathbf{2.0\ mg\ P/l}$$