CIVE 375 ASSIGNMENT 6

① TANK: $L = 18m$ $W = 4.5m$ $D = 3.0m$ $Q = 4500 m^3/d$

p. 8-8 $\forall = 243 m^3$ $v_c = \frac{Q}{L \cdot W} = 55.6 m/d$

$= 2.3 m/h.$

SEE EXCEL sheet.

$\therefore R_T = 82.0\%$

② $v = 9X^2$ (m/hr) $v_c = 1.8$ m/hr

X - weight fraction of particles with $v_s \leq v$

For particles with $v_s \leq v_c \rightarrow 1.8 = 9X_c^2$

$X_c = 0.447.$

weight Frac Removed

For particles with $v_s \geq v_c$ $X = 1 - 0.447 = 0.553.$

recall, when $v_s < v_c$ weight frac removed $= X \cdot \frac{v_s}{v_c}$

$\therefore$ we must integrate $X \frac{v_s}{v_c}$ w.r.t X as $X = 0 \rightarrow 0.447.$ to determine

thus $\int_0^{X_c} \frac{v_s}{v_c} dX = \int_0^{0.447} \frac{9X^2}{1.8} dX = \frac{5}{3} X^3 \Big|_0^{0.447}$

$= 0.149$

$\therefore R_T = 0.553 + 0.149 = 70.2\%$

③ $Q = 950\ m^3/day$

Stokes Law: $$v_s = \frac{g(\rho_p - \rho_w)d_p^2}{18\mu}$$ p. 8-5

$$= \frac{g(G_s - 1)\rho_w d_p^2}{18\mu}.$$

$$\therefore\ v_s \propto (G_s - 1)\cdot d_p^2$$

Since $d_{p\,min,\,sand} > d_{p\,min,\,metal}$ and,
G_s sand $>$ G_s metal, then,
v_s sand $>$ v_s metal

therefore, we must design to settle the metal.

$$v_{s,\,metal} = \frac{9.81\,m}{s^2}\left|\frac{(1.5-1)\,1000\,kg}{m^3}\right|(4.0\times10^{-5}\,m)^2\left|\frac{cm\cdot s}{18\cdot 1.01\times10^{-2}\,g}\right|\frac{1000\,g}{kg}$$

$$= 4.32\times10^{-2}\,cm/s = 1.55\,m/hr. = 37.3\,m/day$$

From $v_c = \frac{Q}{L\cdot W}$, $A_s = L\cdot W = \frac{Q}{v_c} = \frac{950}{37.3} = 25.5\,m^2$

looking at p. 8-10, $L \approx 5W \approx 5H$.

$A_s = L\cdot W = 5W^2 \rightsquigarrow W = 2.3\ m$
$L = 11.3\ m$
$H = 3.0\,m$ (give a little extra)

check reynolds number

$$N_R = \frac{v_s d_p \rho_w}{\mu} = \frac{(4.32\times10^{-2})(4\times10^{-3})(1\,g/cm^3)}{1.01\times10^{-2}\,\frac{g}{cm\cdot s}} = 1.7\times10^{-2}$$

$N_R < 0.3$ $\therefore$ OK.

$$t_o = \frac{\forall}{Q} = \frac{(11.3)(2.3)(3.0)}{950} = 0.08\ days\ \therefore OK$$

TANK Dimensions: $W = 2.3\ m$
$L = 11.3\ m$
$H = 3.0\ m$

④ SEE Excel Sheet

Note $\mu = \dfrac{0.001\ N\cdot s}{m^2}\left|\dfrac{kg\cdot m}{N s^2}\right. = 0.001\ \dfrac{kg}{m\cdot s}$

$v_c = 2.21\times10^{-4}$

check boundary conditions

$1.36\times10^{-4} < v_c < 2.67\times10^{-4}$ ∴ O.K.

⑤ From p. 8-3 in text

$$R_T = \frac{\Delta h_1}{H}\left[\frac{R_1+R_2}{2}\right] + \frac{\Delta h_2}{H}\left[\frac{R_2+R_3}{2}\right] + \cdots \qquad H = 1.2\,m$$

at $t = 20\,min$ $\quad R_T = \dfrac{0.25}{1.2}\left(\dfrac{100+80}{2}\right) + \dfrac{0.95}{1.2}\left(\dfrac{80+70}{2}\right) = 78.1\%$

at $t = 15\,m$ $\quad R_T = \dfrac{0.15}{1.2}(90) + \dfrac{0.15}{1.2}(75) + \dfrac{0.7}{1.2}(65) + \dfrac{0.2}{1.2}(57.5)$

$= 68.1\%$

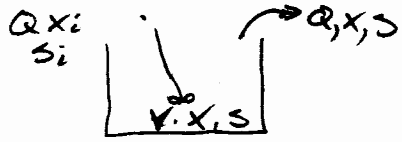
-interpolate

$$\frac{20-t_o}{78.1-74} = \frac{20-15}{78.1-68.1} \quad \cdots \quad t_o = 17.9\ min$$

$$v_c = \frac{H}{t_o} = \frac{1.2}{17.9} = 0.067\ m/min = 4.01\ m/hr. \quad \text{for } R_T = 75\%$$

⑥ Find $r_g(\theta)$ and $S(\theta)$ chapter 14.4 in text.

i) Mass balance (look at example 14.2)



$$\forall \frac{dX}{dt}\cancel{}^{\,0} = QX_i - QX + r_g \forall$$

$$r_g = \frac{Q(X-X_o)}{\forall} \qquad \text{but } \frac{Q}{\forall} = \frac{1}{\theta} \text{ and } X_o = 0$$

$$\therefore\ r_g = \frac{X}{\theta}$$

contd.

(6) cont'd p. 602 of text

ii) $$V\frac{d\cancel{S}^{\,0}}{\cancel{dt}} = QS_o - QS + Vr_o$$ look at example 14.3

where $r_o = \frac{-kSX}{K_s + S}$ (equation 14.2)

$$r_o = \frac{Q(S-S_o)}{V} = \frac{S-S_o}{\theta}$$ but $$r_g = \frac{YkXS}{K_s+S} - k_dX$$ (eq 14.3)

$$\therefore \frac{X}{\theta} = -Y\left(\frac{S-S_o}{\theta}\right) - k_dX \quad \rightarrow X = \frac{Y(S_o-S)}{1+k_d\theta}$$

from $$\cancel{S-S_o} = -\theta\frac{kSX}{K_s+S} = \theta\frac{kSY(\cancel{S-S_o})(1+k_d\theta)^{-1}}{K_s+S}.$$

$$\rightarrow \quad 1 = \frac{\theta kSY}{(1+k_d\theta)(K_s+S)}$$

solve for $$S = \frac{-K_s(1+k_d\theta)}{1+\theta(k_d-kY)}$$

(7) $V = 25\ L$ $BOD_5 = 200\ mg/L$ $\frac{BOD_5}{BOD_u} = 0.75$ $\frac{VSS}{TSS} = 0.85$

CFSTR 1	CFSTR 2
$Q_1 = 5.5\ L/day$	$Q_2 = 3.0\ L/day$
$S_1 = 135.4/0.75 = 180.5\ mg/L$	$S_2 = 35.3/0.75 = 47.1\ mg/L$
$S_o = 250/0.75 = 333.3\ mg/L$	$S_o = 333.3\ mg/L$
$X_1 = 79.1/0.85 = 93.1\ mg/L$	$X_2 = 120.3/0.85 = 141.5\ mg/L$
$\theta_1 = \frac{V}{Q} = 4.5\ days$	$\theta_2 = 8.3\ days$

Use Equations from last Question

(1) $$X = \frac{Y(S_o-S)}{1+k_d\theta}$$ (2) $$S = \frac{-K_s(1+k_d\theta)}{1+\theta(k_d-kY)}.$$

(7) cont'd.

CFSTR 1

From (1)

$$93.1 = \frac{Y(333.3-180.5)}{1+4.5k_d}$$

$$Y = \frac{93.1+355.95k_d}{152.8}$$

$$= 0.61 + 2.33k_d$$

CFSTR 2

$$141.5 = \frac{Y(333.3-47.1)}{1+8.3k_d}$$

$$Y = \frac{141.5+998.5k_d}{286.2}$$

$$= 0.49 + 3.49k_d$$

$$k_d = \frac{0.61-0.49}{3.49-2.33} = 0.10\ d^{-1}$$

$$Y = 0.84$$

From (2)

$$\frac{(1+k_d\theta_1)}{S_1+S_1\theta_1(k_d-kY)} = \frac{(1+k_d\theta_2)}{S_2+S_2\theta_2(k_d-kY)}$$

Sub in k_d, Y, θ solve for $k = 0.247 d^{-1}$

$K_s = 4.2\times10^{-3}$

$\therefore Y = 0.84 \quad k = 0.247 d^{-1} \quad K_s = 4.2\times10^{-3} \quad k_d = 0.1 d^{-1}$.

(8) a)

$$\frac{X}{\theta} = \frac{kYXS_0}{K_s+S_0} - k_dX \qquad \text{at } \theta = \theta_c^m,\ X=1$$

$$\frac{1}{\theta_c^m} = \frac{kYS_0}{K_s+S_0} - k_d$$

$$= \frac{50(0.6)(200)}{50+200} - 0.05$$

$$\frac{1}{\theta_c^m} = 23.95 \qquad \therefore \theta_c^m = 0.042 \text{ days} = 1 \text{ hr.}$$

⑧ b) $\theta_c = 2$ days

i) Find $S = \dfrac{k_s(1+\theta k_d)}{\theta(Yk - k_d)-1} = \dfrac{50(1+2(0.05))}{2(0.6(50)-0.05)-1} = 0.934\ mg/L$

ii) Find $-r_o/X = \dfrac{kS}{K_s+S} = \dfrac{50(0.934)}{50+(0.934)} = 0.92\ d^{-1}$

iii) Find $X = \dfrac{Y(S_o-S)}{1+k_d\theta} = \dfrac{0.6(200-0.934)}{1+0.05(2)} = 108.58\ mg/L$

iv) Find $\dfrac{F}{M} = \dfrac{S_o}{\theta X} = \dfrac{200}{2(108.58)} = 921\ d^{-1}$