Problem Set 5—Key

CENG 340–Introduction to Environmental Engineering
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Problems

1. **(12 pt)** Aeration to convert $[Fe^{2+}]$ to $[Fe^{3+}]$

   Given:

   $[Fe^{2+}]_{in}$ = 7.0 mg/L
   $[Fe^{2+}]_{out}$ = 0.25 mg/L
   $k = 0.175\,\mathrm{min}{-1}$
   $Q = 40{,}000\ \frac{m^3}{d}$

   - CMFR

     $$\frac{dm}{dt} = \dot{m_{in}} - \dot{m_{out}} - \dot{m_{rxn}}$$

     $$0 = QC_{in} \text{ - } QC \text{ - } kCV$$

     $$V = \frac{QC_{in} - QC}{kC} = \frac{40{,}000\,\frac{m^3}{day} \times (7 - 0.25)\,\frac{mg}{L}}{0.25\,\frac{mg}{L} \times 0.175\,\mathrm{min}^{-1} \times \frac{60\,\mathrm{min}}{h} \times \frac{24\,h}{day}} = 4286\,m^3$$

     For CMFR, V = 4286 m^3

     $$\theta = \frac{V}{Q} = \frac{4286\,m^3}{40{,}000\,\frac{m^3}{day}} \times \frac{24\,h}{day} = 2.6\,h$$

     For CMFR, θ = 2.6 h

   - PFR

     $$C_{out} = C_{in} \times e^{-k\frac{V}{Q}}$$

     $$\frac{C_{out}}{C_{in}} = e^{-k\frac{V}{Q}}$$

     $$\ln\left(\frac{C_{out}}{C_{in}}\right) = -k\frac{V}{Q}$$

$$V = -\ln\left(\frac{C_{out}}{C_{in}}\right) \times \frac{40{,}000\,\frac{m^3}{day}}{0.175\,min^{-1}} \times \frac{1\,day}{24\,h} \times \frac{1\,h}{60\,min} = 529\,m^3$$

For PFR, V = 529 m^3

$$\theta = \frac{V}{Q} = \frac{529\,m^3}{40{,}000\,\frac{m^3}{day}} \times \frac{24\,h}{day} = 0.32\,h$$

For PFR, $\theta = 0.32$ h

2. **(12 pt)** Alum and Alkalinity Requirements for Coagulation

$$Al_2(SO_4)_3 \bullet 14\,H_2O + 6\,HCO_3^- \longrightarrow 2\,Al(OH)_{3(s)} + 3\,SO_4^{2-} + 14\,H_2O + 6\,CO_2$$

Alkalinty: 6 moles of HCO_3^- (or 6 equivalents of alkalinity) are consumed per mole of alum added.

$$\text{Alkalinity Required} = \frac{12.5\,\text{mg Alum}}{\text{L}} \times \frac{1\,\text{mole alum}}{594\,\text{g alum}} \times \frac{6\,\text{eq alk}}{1\,\text{mole alum}} \times \frac{50\,\text{g CaCO}_3}{1\,\text{eq alk}}$$

$$\text{Alkalinity Required} = 6.3\,\text{mg/L}$$

Alum

$$\text{Alum Required} = 12.5\,\frac{\text{mg}}{\text{L}} \times 50 \times 10^6\,\frac{\text{gal}}{\text{day}} \times \frac{3.78\,\text{L}}{\text{gal}} \times 365\,\frac{\text{day}}{\text{year}} \times \frac{1\,\text{kg}}{10^6\,\text{mg}}$$

$$\text{AlumRequired} = 862,300\,\text{kg/year}$$

3. **WATER SOFTENING**

4. **(12 pt)** Problem 10.8 in the Textbook:

Size a rapid-mix (coagulation) tank:

Given Q = 50 $\frac{m^3}{day}$

Assume $\theta = 1$ to 2 min

For $\theta = 1$ min:

$$V = Q \times \theta = 50\frac{\mathrm{m}^3}{\mathrm{day}} \times 1\,\mathrm{min} \times \frac{1\,\mathrm{day}}{24\,\mathrm{h}} \times \frac{1\,\mathrm{h}}{60\,\mathrm{min}}$$

$V = 0.035\ \mathrm{m}^3$

For $\theta = 2$ min
$V = 0.07\ \mathrm{m}^3$

Acceptable values of $V = 0.035$–$0.07\ \mathrm{m}^3$

Calculate the power needed for mixing:

Assume $\bar{G} = 600$ to $1000\ \mathrm{s}^{-1}$

For 12 ^{0}C:

Use the table inside the cover of the text book and interpolate to calculate the dynamic viscosity of water at 12 ^{0}C.

For water at $T = 12\ ^0$C, $\mu = 1.24\times10^{-3}\ \frac{\mathrm{kg}}{\mathrm{m}\times\mathrm{s}} = \frac{\mathrm{N}\times\mathrm{s}^2}{\mathrm{m}^2\times\mathrm{s}} = \frac{\mathrm{N}\times\mathrm{s}}{\mathrm{m}^2}$

$P = \bar{G}^2 \times \mu \times V$

For $\bar{G} = 800\ \mathrm{s}^{-1}$:

$P = (800\mathrm{s}^{-1})^2 \times 1.24 \times 10^{-3}\ \frac{\mathrm{N}\times\mathrm{s}}{\mathrm{m}^2} \times 0.035\,\mathrm{m}^3 = 28\ \frac{\mathrm{N}\times\mathrm{m}}{\mathrm{s}} = 28\ \frac{\mathrm{J}}{\mathrm{s}} = 28\,\mathrm{W}$

Acceptable valuse of P: 15.6 to 87 Watts

To calculate Power at 24 ^{0}C:

Use the table inside the cover of the text book and interpolate to calculate the dynamic viscosity of water at 24 ^{0}C:

$\mu = 9.13\times10^{-4}$

Same calculations as for 24 ^{0}C.

Acceptable valuse of P: 11.5 to 64 Watts.