Homework 2

Problem 1

\[ C_{in} = 150 \text{ mg/L} \]

\[ Q = 380 \frac{L}{min} \quad k = 0.4 \text{ hr}^{-1} \]

\[ C_{out} = C_{in} \exp(-kT_R) \]

\[ D_{esired} = 20 \text{ mg/L} \]

\[ \frac{C_{out}}{C_{in}} = \frac{20}{150} = 0.13 = \exp(-kT_R) \]

\[ -kT_R = \ln \left( \frac{C_{out}}{C_{in}} \right) \]

\[ T_R = -\frac{1}{k} \ln \left( \frac{C_{out}}{C_{in}} \right) \]

\[ = -\frac{1}{0.4 \text{ hr}^{-1}} \ln (0.13) \]

\[ = 5.0 \text{ hr} \]

\[ T_R = \frac{T}{Q} \]

\[ T = T_R Q = 5.0 \text{ hr} \cdot 380 \frac{L}{min} \cdot 60 \frac{min}{hr} \]

\[ = 114,000 \text{ L} = 114 \text{ m}^3 \]

b. See spreadsheet following Problem 2
Problem 2

\[ k = 0.4 \text{ hr}^{-1} \]

\[ C_{in} = 150 \text{ mg/L} \quad C_{out} \]

\[ \dot{Q} = 380 \text{ L/min} \]

a. Assume steady-state

\[ C_{out} = C_{in} \cdot \frac{1}{1 + KT_R} \]

Desired \( C_{out} = 20 \text{ mg/L} \)

\[ \frac{C_{out}}{C_{in}} = \frac{1}{1 + KT_R} \]

\[ 1 + KT_R = \frac{C_{in}}{C_{out}} \]

\[ TR = (\frac{C_{in}}{C_{out}} - 1) \cdot \frac{1}{K} \]

\[ = (\frac{150}{20} - 1) \cdot \frac{1}{0.4} \]

\[ = 16.25 \text{ hours} \]

Much longer than PFR!

\[ V = TR \cdot \dot{Q} = 16.25 \text{ hr} \cdot 380 \frac{\text{L}}{\text{min}} \cdot 60 \frac{\text{min}}{\text{hr}} \]

\[ = 370,500 \text{ L} = 370 \text{ m}^3 \]

3.29 times bigger!

b. See spreadsheet
Problem 2 (cont)

c. 80% removal implies \( \frac{C_{out}}{C_{in}} = 0.2 \)

For PFR \( \frac{C_{out}}{C_{in}} = e^{-KT_{PF}} \rightarrow T_{PF} = -\frac{1}{K} \ln \frac{C_{out}}{C_{in}} \)

For FMT \( \frac{C_{out}}{C_{in}} = \frac{1}{1 + KT_{FMT}} \rightarrow T_{FMT} = \frac{1}{K} \left( \frac{C_{in}}{C_{out}} - 1 \right) \)

\( V_{PF} = Q \cdot T_{PF} \)

\( V_{FMT} = Q \cdot T_{FMT} \)

\( \frac{V_{FMT}}{V_{PF}} \cdot \frac{T_{FMT}}{T_{PF}} = \frac{\frac{1}{K} \left( \frac{C_{in}}{C_{out}} - 1 \right)}{-\frac{1}{K} \left( \ln \frac{C_{out}}{C_{in}} \right)} = \frac{C_{in}}{C_{out}} - 1 \)

\( = \frac{150}{20} - 1 = 3.2 \) times larger
Reactor performance for $k = 0.4/\text{hr}$

- Fully-mixed tank
- Plug-flow reactor

Percent removed vs. Residence time (hours)
Reactor performance for $k = 0.4/hr$

- Fully-mixed tank
- Plug-flow reactor