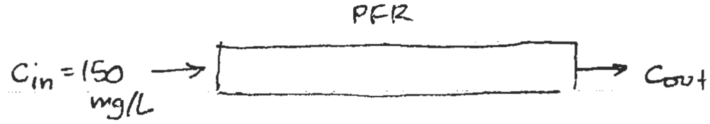
1.85 Homework 2

Problem 1



$Q = 380 \frac{L}{min}$ $\qquad k = 0.4\ hr^{-1}$

a. Assume steady-state $\qquad C_{out} = C_{in} \exp(-kT_R)$

Desired $\quad C_{out} = 20\ mg/L$

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

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

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

$$= -\frac{1}{0.4\ hr^{-1}} \ln(0.13)$$

$$= 5.0\ hr$$

$$T_R = \frac{\forall}{Q}$$

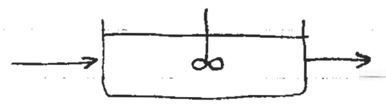
$$\forall = T_R Q = 5.0\ hr \cdot 380 \frac{L}{min} \cdot 60 \frac{min}{hr}$$

$$= 114{,}000\ L = 114\ m^3$$

b. See spreadsheet following Problem 2

Problem 2

$K = 0.4 \, hr^{-1}$



$C_{in} = 150 \, mg/L$ $\qquad$ C_{out}

$Q = 380 \, L/min$

a. Assume steady-state $\qquad C_{out} = C_{in} \dfrac{1}{1 + K T_R}$

Desired $C_{out} = 20 \, mg/L$

$$\frac{C_{out}}{C_{in}} = \frac{1}{1 + K T_R}$$

$$1 + K T_R = \frac{C_{in}}{C_{out}}$$

$$T_R = \left(\frac{C_{in}}{C_{out}} - 1 \right) \frac{1}{K}$$

$$= \left(\frac{150}{20} - 1 \right) \frac{1}{0.4}$$

$$= 16.25 \text{ hours}$$

Much longer than PFR!

$$\forall = T_R Q = 16.25 \, hr \;\; 380 \, \frac{L}{min} \;\; 60 \, \frac{min}{hr}$$

$$= 370{,}500 \, L = 370 \, m^3$$

3.25 times bigger!

b. See spreadsheet

Problem 2 (con't)

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

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

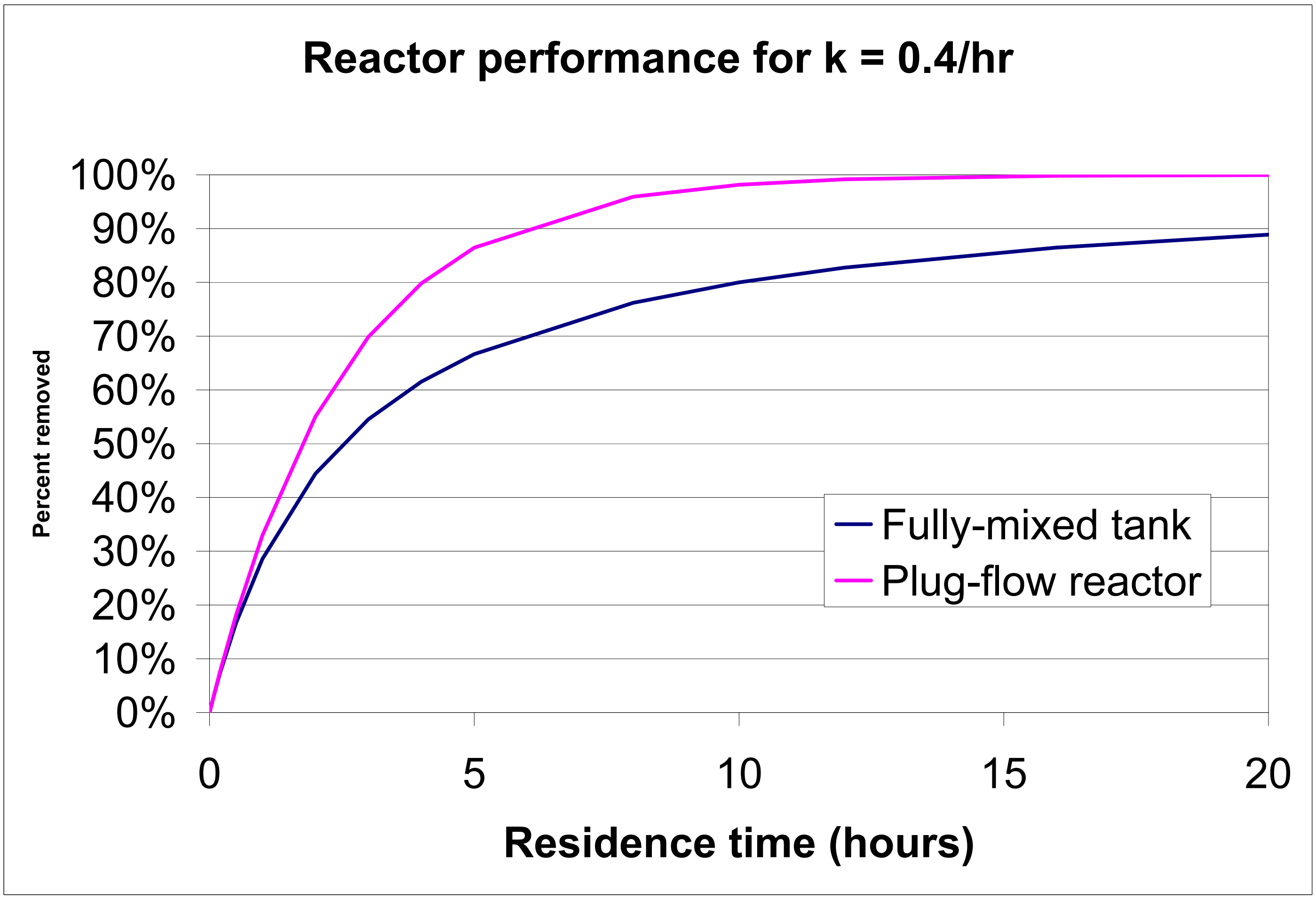
For FMT $\frac{C_{out}}{C_{in}} = \frac{1}{1+KT_{FMT}} \rightarrow T_{FMT} = \frac{1}{K}\left(\frac{C_{in}}{C_{out}} - 1\right)$

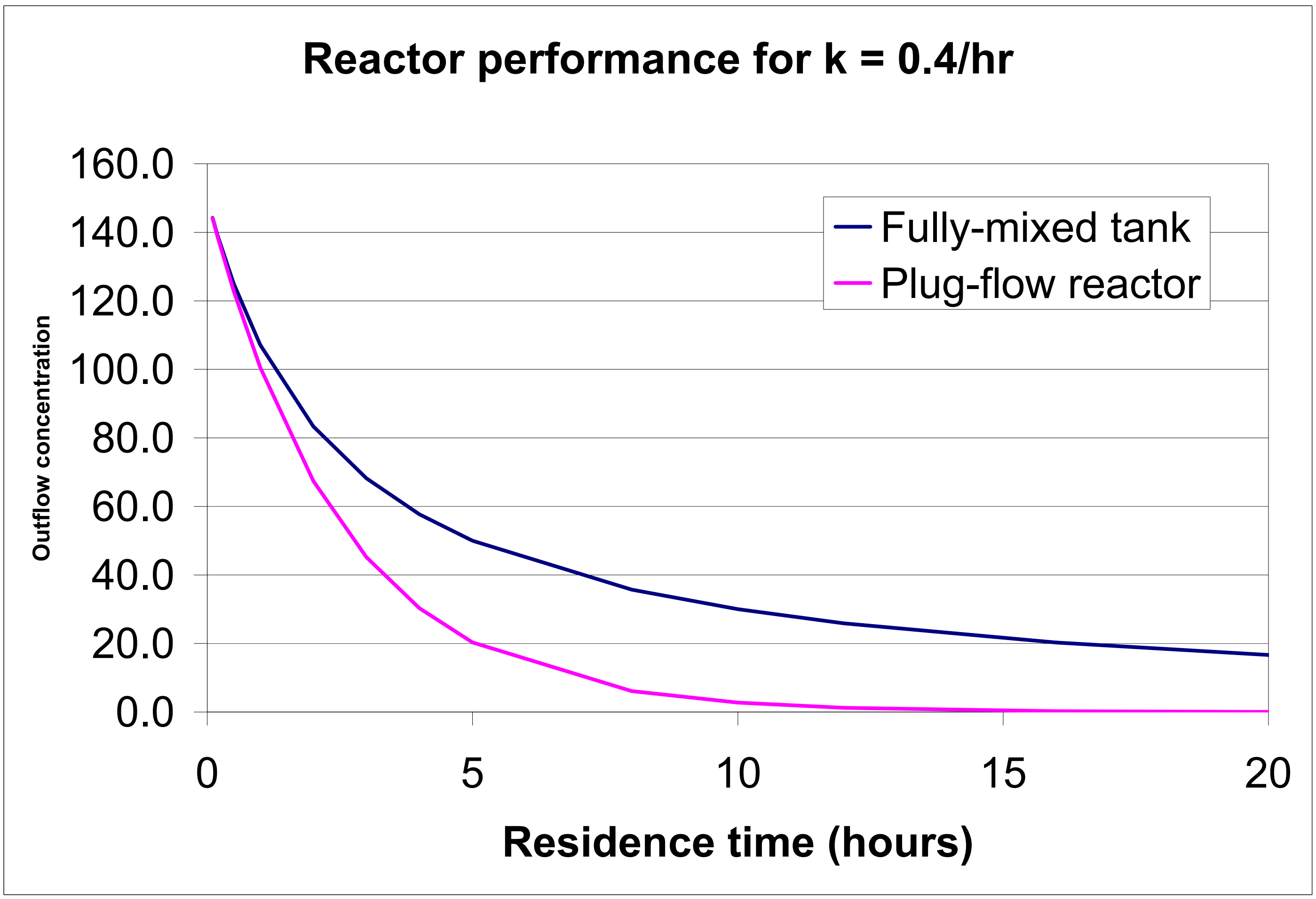
$\forall_{PF} = Q\, T_{PF}$

$\forall_{FMT} = Q\, T_{FMT}$

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

$$= \frac{\frac{150}{20} - 1}{\ln\left(\frac{150}{20}\right)} = 3.2 \text{ times larger}$$


Reactor performance for k = 0.4/hr
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent removed
0
5
10
15
20
Residence time (hours)
Fully-mixed tank
Plug-flow reactor



Reactor performance for k = 0.4/hr
Fully-mixed tank
Plug-flow reactor
Outflow concentration
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
5
10
15
20
Residence time (hours)