Homework 2

a. Fully-mixed circular tank 80 ft in diameter

$$C = \frac{C_{in}}{1 + Kt_R}$$

$$t_R = \frac{V}{Q} = \frac{\pi r^2 H}{Q}$$

Given:
$Q = 0.2$ mgd
$C_{in} = 200$ mg/L COD
$K = 1$ day^{-1}
$r = 40$ ft
$t_R = 1$ day

$$H = \frac{t_R Q}{\pi r^2} = \frac{1 \text{ day} \cdot 0.2 \times 10^6 \frac{\text{gal}}{\text{d}} \cdot \frac{1}{7.48} \frac{\text{ft}^3}{\text{gal}}}{\pi \cdot (40 \text{ ft})^2}$$

$$= 5.3 \text{ ft deep}$$

$$C = \frac{C_{in}}{1 + Kt_R} = \frac{200 \text{ mg/L}}{1 + 1 \text{ day}^{-1} \cdot 1 \text{ day}} = 100 \text{ mg/L}$$

50% removal

b. Rectangular tank with baffle

$L = 100$ ft $W = 50$ ft

$$t_R = \frac{L W H}{Q} = 1 \text{ day}$$

$$H = \frac{t_R Q}{W L} = \frac{1 \text{ day} \cdot 0.2\times10^6 \frac{\text{gal}}{\text{d}} \cdot \frac{1}{7.48} \frac{\text{ft}^3}{\text{gal}}}{100 \text{ ft} \cdot 50 \text{ ft}}$$

$$= 5.3 \text{ feet deep}$$

Consider as dispersed flow reactor (note, use half-width for baffled tank)

Estimate $D = 0.03 \dfrac{UW^2}{R_h}$

$$R_h = \frac{\text{area}}{\text{perimeter}} = \frac{5.3 \times 25}{25 + 2 \cdot 5.3} = 3.7 \text{ ft}$$

$$U = \frac{Q}{A} = \frac{0.2\times10^6 \frac{\text{gal}}{\text{day}} \cdot \frac{1}{7.48} \frac{\text{ft}^3}{\text{gal}}}{5.3 \times 25 \text{ ft}^2}$$

$$= 200 \text{ ft/d}$$

$$D = 0.03 \frac{200 \text{ ft/d} \; (25 \text{ ft})^2}{3.7 \text{ ft}}$$

$$= 1000 \text{ ft}^2/\text{d}$$

Steady-state solution:

$$\frac{C}{C_{in}} = \frac{4a \exp(P/2)}{(1+a)^2 \exp(aP/2) - (1-a)^2 \exp(-aP/2)}$$

$$P = \frac{UL}{D} = \frac{200 \text{ ft/d} \; 200 \text{ ft}}{1000 \text{ ft}^2/\text{d}} = 40$$

Note, L is doubled for baffled tank

$$a = \sqrt{1 + \frac{4Kt_R}{P}}$$

$$a = \sqrt{1 + \frac{4 \ 1/\text{day} \ 1 \ \text{day}}{40}} = 1.05$$

$$\frac{c}{c_{in}} = 0.38$$

$c = 76$ mg/L   62% removal

If tank is assumed to provide plug flow:

$$\frac{c}{c_{in}} = e^{-k t_R}$$

$$= 0.37$$

$c = 74$ mg/L   63% removal

Baffled tank is nearly plug flow!

c. $H = 5.3$ feet deep (same as Part b)

$R_h = 4.4$ ft

$U = 100$ ft/d

$D = 1700$ ft²/d

$\mathbb{P} = 5.8$

$a = 1.3$

$\frac{c}{c_{in}} = 0.41$ $c = 82$ mg/L

59% removal

d. Three circular fully-mixed tanks

t_R' for each tank $= \frac{1}{3}$ day

$$\frac{t_R}{3} = \frac{1}{3}\text{ day} = \frac{\pi r^2 H}{Q}$$

Use same depth as single tank: $H = 5.3$ ft

$$r = \left[\frac{\frac{1}{3}\text{ day} \cdot 0.2\times10^6 \frac{\text{gal}}{\text{day}} \cdot \frac{1}{7.48} \frac{\text{ft}^3}{\text{gal}}}{\pi \quad 5.3\text{ ft}} \right]^{1/2}$$

$$= 23 \text{ feet}$$

$$\frac{C}{C_{in}} = \frac{1}{(1 + Kt_R')^3}$$

$$= \frac{1}{\left(1 + 1\,\text{day}^{-1} \cdot \frac{1}{3}\text{ day}\right)^3} = 0.42$$

$C = 84$ mg/L 58% removal

e Comparison

	Area (ft^2)	Effluent conc (mg/L)	% Removal
a	5000	100	50
b	5000	76	62
c	5000	82	59
d	5000	84	58

Option b gives best performance but is much more expensive than c which gives nearly as good performance. Need a cost analysis to decide.