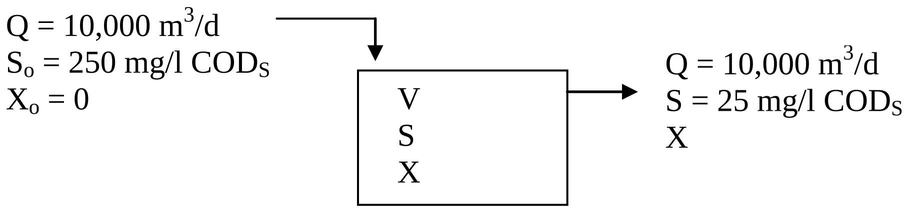
CVEN 5534: Wastewater Treatment
Fall 2010

Assignment 4: Due Thursday, Oct. 14

1. A wastewater containing 250 mg/l soluble COD is to be treated in a CSTR so that the effluent COD is less than 25 mg/l. The flow rate is 10,000 $m^3$/day




Assuming Monod kinetics, steady-state operation of the CSTR and neglecting cell decay:

$$\mu = \hat{\mu}\frac{S}{K_S + S} \text{ and } -r_S = \frac{\mu X}{Y}$$

Where $\hat{\mu}$ = max. specific cell growth rate = 2 $d^{-1}$
S = soluble $COD_S$ concentration, mg/l
$K_S$ = half-saturation constant = 50 mg/l $COD_S$
X = heterotrophic cell concentration, mg-$COD_X$/l
Y = COD yield = 0.6 g-$COD_X$/g-$COD_S$

a. What is the minimum hydraulic residence time, $\tau$, before washout occurs?
b. What reactor volume is required for 90% COD removal?
c. What is the effluent cell concentration?

d. Compare the volume of an ideal plug flow reactor required for the same level of COD removal and the same kinetic model.

e. Plot S vs $\tau$ for the CSTR and PFR

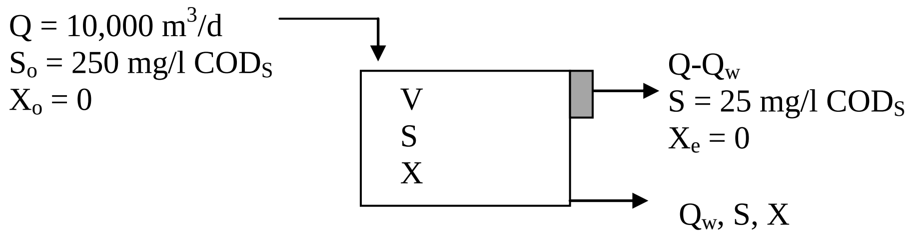
2. Wastewater containing 300 g/$m^3$ COD is to be treated for 85% COD removal. The reaction rate is assumed to be first order with respect to COD concentration because the concentration of cells is constant.

$$r_S = -kS$$

where: $r_S$ = rate of COD consumption (g/$m^3$/d), k = first-order reaction coefficient = 5 $d^{-1}$, and $S_S$ = COD concentration (g/$m^3$)

a. Compare the required system volumes for
   i. An ideal single tank CSTR
   ii. An ideal plug flow reactor
   iii. A CSTR cascade with 2 cells
   iv. A CSTR cascade with 4 cells
b. How will the ratio of required volumes change for 99% removal?

3. Consider a CSTR where cells are perfectly separated from the effluent and are wasted in a separate smaller flow which allows them to accumulate in the CSTR to a higher concentration than a CSTR with no enhanced cell retention.




Assuming Monod kinetics, now with decay,

$$r_X = (\mu - b)X$$

and as in #1

$$\mu = \hat{\mu}\frac{S}{K_S+S} \text{ and } -r_S = \frac{\mu X}{Y}$$

Assume the same wastewater characteristics, effluent COD limit and kinetic parameters as in problem 1 <u>and</u> b = 0.1 $d^{-1}$.

Also 2 parameters are now available to describe CSTR conditions:

$$\tau = \frac{V}{Q} \text{ and } \theta = \frac{V}{Q_w}$$

Where Θ is called the average solids residence time (SRT).

a. Write steady state mass balances on cells (X) and $COD_S$ (S) and solve to get formulas for
   i. S as a function of the kinetic and CSTR parameters
   ii. X as a function of kinetic and CSTR parameters
b. If the cell wasting flow rate, $Q_w = 300\ m^3$/day what is the CSTR cell concentration and the required CSTR volume?
c. Compare V and X to the values you got for the CSTR in problem 1.