CEE 6570: Biological Processes
Problem Set 3
Due: Wednesday, March 7th

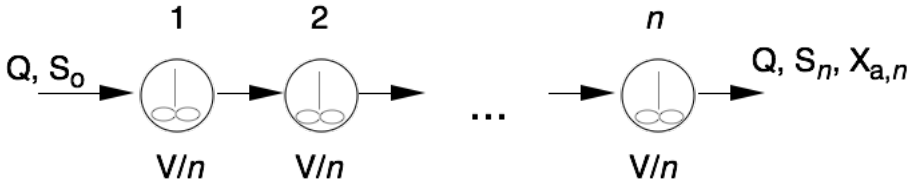
Each Question is Worth 2 Points

1. Suppose you were interested — not in treating a waste — but in production of microbes. Your objective is to maximize the kg active biomass per kg of electron donor fed.

   (a) Of the organic electron donors listed in Table 2.3 from Rittman and McCarty (available on Blackboard), which would be the best choice (if all donors cost the same per eeq of donor)?

   (b) How would you determine the optimum solids retention time for this objective? You don't need to provide a numerical answer to this question, just a description of how you might go about answering it.

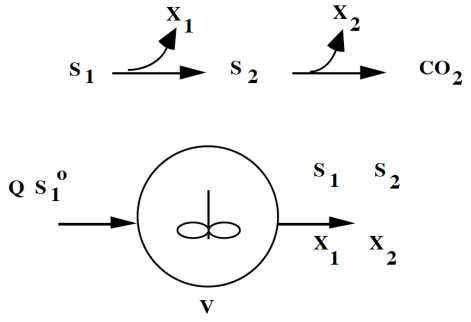
2. A total reactor volume, V, is divided into a series of *n* identical CSTRs (without biomass recycle) — each of volume V/*n*.



   For a single CSTR reactor, we normally define kinetic failure in terms of a minimum retention time (V/Q), below which the reactor cannot operate.

   In the case of the above series of CSTRs, does the number of reactors into which V is divided (*n*) affect success or failure? Explain.

3. This problem explores how a substrate utilization associated product (UAP) is further metabolized in a CSTR bioreactor.

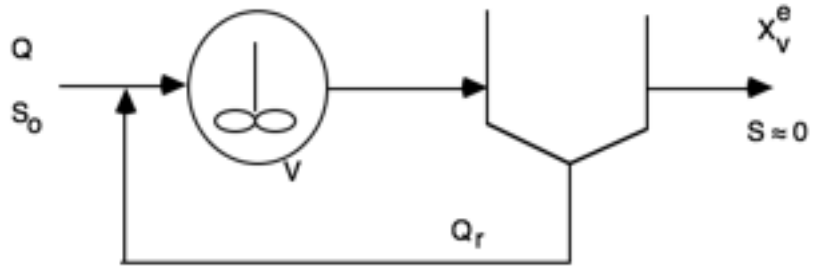


A CSTR system (without recycle, i.e. no active biomass in the influent) of volume V receives a flow Q containing a concentration of substrate, $S_1°$. Organism X_1 uses S_1 for both growth and energy. Its use of S_1 for energy results in the formation of a soluble product S_2, which is the growth and energy substrate for a second organism, X_2. Assuming the usual kinetic

model, and that kinetic constants Y_1, $\hat{q}_1$, K_1, b_1, and Y_2, $\hat{q}_2$, K_2, b_2 may be defined for the two organisms:

(a) Derive an equation for X_1 and S_1 (where X_1 refers to active biomass).
(b) Derive an equation for X_2 and S_2 (where X_2 refers to active biomass). The result should be a function of kinetic constants given above and other common parameters used in the course, like f_e or f_s. (**Hint**: Consider that not all of S_1 consumed goes to form S_2, since some fraction of the electrons from S_1 f_s goes to synthesis of X_1.)
(c) Given a value for influent substrate concentration $S_1°$, what is the θ_x^{min} <u>for the system</u> as a function of the kinetic constants given above and any terms defined in part (b)? (i.e., what is the θ_x^{min} for the system if your goal is to achieve some reduction of both S_1 and S_2?).

4. An extended-aeration activated sludge process is operated with no intentional wasting of solids (i.e., the only solids wasting occurs because of solids passing over the weirs into the effluent).



Assuming:

No solids in the influent;

Y = 0.5 g X_a g BOD^{-1};

b = 0.1 day^{-1}

What is the effective solids retention time for this plant if the influent BOD is 300 mg/L and the effluent contains 50 mg/L VSS?

5. The purpose of this question is to examine the effect of θ_x on sludge production. An activated-sludge plant receives a flow with the following composition:

$Q = 10^8$ L/d

S_O = influent BOD = 200 mg/L

$X_v°$= influent VSS = 100 mg/L

$f_d°$ = biodegradable fraction of $X_v°$ = 0.8

(a) Assuming Y = 0.5 g X_a·g BOD^{-1}, b = 0.1 day^{-1}, $\hat{q}$ = 8 g BOD· $g^{-1}X_a$· day^{-1}, and K = 25 mg BOD·L^{-1}, estimate the kg/d of VSS wasted from the plant as a function of θ_x, for values of θ_x between θ_x^{min} and 20 days. Plot your results (using Excel, Matlab, Python, or the software of your choice).

(b) Estimate the kg/d of *biodegradable* VSS wasted from the plant for the same range of θ_x values.

(c) Waste-activated sludge (WAS) is commonly sent to an anaerobic digester (after thickening) for methanogenic treatment of biodegradable VSS and production of methane as a biofuel. The non-biodegradable residue must be ultimately disposed of, which is expensive and contributes to the life cycle costs and life cycle environmental impacts of wastewater treatment. What do you conclude about the effect of θ_x in the activated sludge process upon the kg/d of residue solids expected after anaerobic digestion of WAS? Is there an optimal θ_x to either optimize the amount of biodegradable VSS for methanogenic treatment, or to minimize the amount of non-biodegradable VSS?