CEE 6570: Biological Processes

Problem Set 2

Due: Wednesday, February 21st

1. (3 points). Glycine is a biodegradable amino acid that can serve as a growth and energy substrate, as well as the source of NH_4^+, for organism X_1. The biodegradation of glycine releases NH_4^+ into solution which can then be used as an N-source for another organism, X_2. (Assume that biodegradation of glycine by X_1 and the biosynthesis of X_1 using N from glycine happen simultaneously). If 1 mol of glycine is added to a 1 L aerobic batch reactor containing a mixed culture of X_1 and X_2:

   a. What are f_s° and f_e°? (you can assume that no electrons are used for cellular maintenance, and assume ε=0.6 and ΔG_{pc} = 18.8 KJ/eeq. Also assume that all of the N from glycine is used by X_1 before being available to X_2)

   b. How much NH_4^+ (in mol/L) will be available for X_2?

   c. What fraction of the N in glycine was used by X_1 for cell synthesis?

2. (2 points). A wastewater is to be treated aerobically in a CSTR with no recycle. The following kinetic constants apply: K = 50 mg BOD/L; $\hat{q}$ = 5.0 mg BOD_L/mg X_a/day; b = 0.06 d^{-1}; and Y = 0.60 g X_a/g BOD. The influent substrate concentration is 200 mg BOD/L.

   a. Determine θ_x^{min}

   b. Using a design value of θ_x = 2 d and the constants provided above, what are (i) the concentration of substrate and active biomass in the effluent and (ii) the biomass-normalized substrate utilization rate?

3. (3 points). A soluble organic waste from a potato processor must be treated prior to discharge. As a preliminary step to the design of a biological wastewater treatment facility, a bench-scale experiment was set up to determine the kinetic coefficients for the wastewater. Five different 5-liter aerobic reactors (completely-mixed, with no recycle) were fed the waste at a strength of 1,000 mg BOD·L^{-1}. The flow rate to each reactor was different, thus achieving different operating θ_x values for each. At steady-state, the following data were obtained:

SRT (days)	S (mg BOD/L)	X_a (mg/L)
0.4	155	335
0.6	60	360
1	27	352
2	12	330
3	10	300

   a. Using a graphical method, determine the kinetic coefficients Y and b from the experimental data. **Hint**: Write an expression for SRT as a function of S_0, S, θ_x,

and X_a and the unknown parameters Y and b. Remember that at steady-state in a CSTR w/out recycle, the substrate mass balance gives:
$(-dS/dt)_{utilization} = Q(S_0-S)/V$

b. Determine the kinetic coefficients $\hat{q}$ and K from the experimental data. **Hint**: First write an expression for the biomass-normalized substrate utilization rate in terms of S, $\hat{q}$, and K. There are two ways to estimate the parameters. The <u>first option</u> is to linearize the equation and estimate the parameters graphically, analogous to the Lineweaver-Burke approach for estimating parameters in the Michaelis-Menten Equation. Transforming nonlinear equations into linear equations can lead to errors in parameter estimation, so the <u>second option</u> is to use nonlinear least-squares regression with, for example, the Matlab function nlinfit, to determine the model coefficients.

c. **2 Points of Extra Credit**: Compare the model coefficient estimates based on the linearization approach and the nonlinear regression approach, showing which is more accurate based on a comparison of model fits with the two different parameter sets to the experimental data.

4. (2 points) Two organisms X_1 and X_2 compete for the same growth-limiting substrate S in a CSTR w/out recycle and with no influent biomass. The solids retention time in the reactor is θ_x = 0.75 days. The kinetic constants for X_1 and X_2 are:

	X_1	X_2
Y (mg X_a/mg S)	0.63	0.63
K (mg/L)	30	80
$\hat{q}$ (mg S/mg X_a – day)	6	6
b (1/day)	0.2	0.2

Will both X_1 and X_2 be able to survive at steady-state without being washed out? If not, which one will survive and what will the steady-state substrate concentration be? There is an intuitive answer to this question that you could provide without doing any calculations, though it will be hard to get partial credit in that case if it's not correct.