Problem Set 9

CEEG 340–Introduction to Environmental Engineering

Instructor: Deborah Sills

November 8, 2019

Due Date

Friday, November 16 by 11:59 PM

1. *(25 pts)* **Monod Kinetics**

   A kinetic study of the bacterial utilization of methanol was conducted and yielded the following data:

Substrate, S (mg/L)	**-dS/dt ($\frac{\text{mg}}{\text{L}\times\text{hr}}$)**
2	1
4	1.5
6	1.8
8	2
10	2.14

   S = concentration of methanol.

   In addition, biomass concentration (bacterial concentration, X) was maintained at a constant 100 mg/L during the study.

   (a) From this data, determine the parameters for a Monod substrate utilization model, presented below. (This model is similar to the model presented in class for μ, and it shows that S and X are related by a constant, which is incorporated into μ_{max}.) Hint: Use Kaleidegraph to fit the non-linear equation to the data and calculate μ_{max} and K_s. Don't try to determine X with your model fit; instead input X as the value given in the problem statement.

   $$\frac{\mathrm{dS}}{\mathrm{dt}} = -\frac{\mu_{\mathrm{max}}\mathrm{XS}}{\mathrm{K_s} + \mathrm{S}}$$

   (b) This model can be used to predict the concentration of methanol in a well-mixed pond that has an indigenous bacteria population close to that used in the kinetic study above.The concentration of the bacteria in the pond is, however, 10% of that of the kinetic study, and this bacterial concentration is relatively constant in the pond.

   Determine the methanol concentration in the pond 5 days after the pond was contaminated with 200 mg/L of methanol. Assume the pond behaves as a batch reactor (no inflow/outflow) and that no methanol escapes by evaporation. Hint: employ the "diphasic" or "mixed-order" Monod model

2. *(25 pts)* **Microbial Growth Kinetics—Batch Reactor**

Assume:

A batch reactor with Q = 0

$\mu_{max} = 6.5 \text{ day}^{-1}$

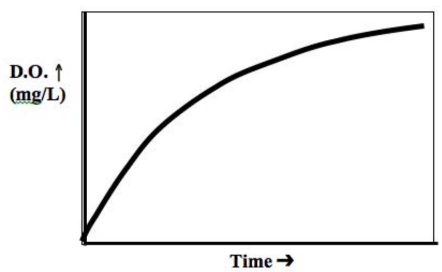
$K_s = 35 \frac{\text{mg BOD}_u}{\text{L}}$

$k_d = 0.10 \text{ day}^{-1}$

(a) If the food supply is unlimited and large (promoting exponential growth), and the initial concentration of bacteria is 0.25 $\frac{\text{mg cells}}{\text{L}}$, then what will be the biomass concentration, X, (in mg cells/L) at the end of three days?

(b) Bacteria multiply by binary fission, doubling their number with each new generation. Calculate the "doubling time" (in hours) for this system (i.e., with unlimited substrate).

3. *(25 pts)* **Aeration:** The curve shown below illustrates results from a test of aeration equipment that is being evaluated for oxygen transfer in a bioreactor system to be used for BOD removal. The test was conducted at 20^0 C



To start the test, the D.O. concentration was depleted to zero by addition of a chemical, and then the aeration equipment was turned on to restore O_2 to an otherwise pure water (zero BOD). If the D.O. level achieved was 5 mg/L after 30 minutes, what was the mass transfer rate for oxygen achieved by the equipment at 30 minutes? (You may assume that the atmospheric partial pressure of oxygen was 0.21 atmospheres, and the Henry's Law constant for oxygen at the test temperature of 20^0 C is 43.8 $\frac{\text{mg}}{\text{L}\times\text{atm}}$.)

4. In class we watched a video about Bill Gates's "Reinvent the Toilet" campaign, and we learned that energy can be recovered from wastewater, by harnessing microbial activity and using anaerobic digestion (AD). Kevin then asked how much energy can we really produce from such waste, and how does this compare to global energy consumption.
To answer Kevin's question, let's do a "back-of-the-envelope" calculation:

Given an annual production of manure (human and animal) of 3.9×10^{12} kg (as dry material), a methane yield of 200 mL CH_4 per g solids added to AD (conservative estimate), calculate the volume of methane that can be produced from anaerobic (without oxygen) biological treatment of manure.

3.8×10^{12} m^3 of natural gas (99 % methane was consumed in 2018. What fraction of natural gas demand can be satisfied by biogas?