Problem Set 10

CENG 340–Introduction to Environmental Engineering
Instructor: Deborah Sills
December 2, 2013

Due Date and Grading

Monday, December 9th, by 5pm.

Learning Objectives

1. Be familiar with the basic design options for ecological sanitation (ECOSAN) latrines.
2. Integrate mass balances with the Monod Model (for microbial growth kinetics) to develop design equations for biological wastewater treatment reactors.
3. Relate solids retention time (SRT), food-to-microorganism ratio, sludge wasting, and microbial growth kinetics to the design and operation of biological treatment reactors.

Relevant Reading

1. Ecosan Technical Handbook (link included as part of Problem 1): http://www.wateraid.org/ /media/Publications/construction-ecological-sanitation-latrine-technical-handbook.pdf
2. Textbook: pp. 475–489

Problems

1. *(20 pts)* **Ecological Sanitaion (Ecosan) Latrines**: Read the following Technical Handbook on construction of Ecosan Latrines published by *Water Aid*, and propose a design recommendation to an under-served community. Your design recommendation should include three sections:

   (a) A *brief* introduction (no more than one paragraph) to Ecosan and why you recommend this technology.

   (b) A *brief* (no more than one paragraph) rationale as to why you recommend a specific Ecosan system—one of the urine diversion systems (single or double vault), or a composting latrine (may include urine diversion or not; may be single or dual chamber).

   (c) A *brief* (no more than one paragraph) description of the latrine design and how the latrine works.

(d) A *brief* (no more than one paragraph) list of operating and maintenance procedures required for the latrine to function properly, and how you propose to ensure the latrine is maintained appropriately.

2. *(14 pts)* **Microbial Growth Kinetics—Batch Reactor**

Assume:

A batch reactor with Q = 0

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

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

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

(a) If the food supply is unlimited and large (promoting exponential growth), and the initial concentration of bacteria is 0.25 $\frac{\text{mg X}}{\text{L}}$, then what will be the biomass concentration, X, (in mg cells/L) at the end of three days? *Answer: 5.5×10^7 $\frac{mg\,cells}{L}$*

(b) Bacteria multiply by binary fission, doubling their number with each new generation. Calculate the "generation time" (in days) for this system (i.e., the length of time it takes for the population to double). *Answer: 2.6 hours*

3. *(14 pts)* **Microbial Growth Kinetics—CMFR**
Assume that the BOD removal rate can be described by the following equation that is first order with respect to both cell concentration (X) and BOD concentration (S):

$$-\frac{\text{dS}}{\text{dt}} = \text{kXS} \tag{1}$$

where: k = a first-order, growth-rate constant (day^{-1}). Also, assume that cell growth rate is directly proportional to the rate of BOD removal:

$$\frac{\text{dX}}{\text{dt}} = -\text{Y}\frac{\text{dS}}{\text{dt}} \tag{2}$$

where: Y = yield coefficient $\left(\frac{\text{mg cells}}{\text{mg BOD consumed}}\right)$. And assume that cell death is first order with respect to cell concentration:

$$\frac{\text{dX}}{\text{dt}} = -\text{k}_\text{d}\text{X} \tag{3}$$

where: k_d = a first-order, decay-rate constant (day^{-1}).

Derive an equation to predict the steady state effluent BOD concentration (S) from a CMFR if: S_0 = influent BOD concentration (mg/L); Q = influent flow rate (L/day); V = CMFR reactor volume (L); X_0= influent cell concentration = zero; and the CMFR has no recycle flow.

4. *(14 pts)*

   (a) A waste is to be treated aerobically in a CMFR with no recycle. Determine the critical SRT (θ_{cmin}) using the following constants:

   $\mu_{max} = 4.2$ day^{-1}

   $K_s = 40$ mg/L

   $k_d = 0.1$ day^{-1}

   The input waste concentration, S_0, is 200 mg/L BOD_u.
   Answer: 7.1 hours

   (b) Assuming that the design SRT (θ_c value) must be at least $20\times\theta_{cmin}$ to provide a safety factor against wash out of cells, calculate the effluent substrate concentration, S. *Answer: 2.75 mg/L*

5. *(10 pts)* Textbook: 11.6 *Answer: 656 kg/day*

6. *(14 pts)*Textbook: 11.7 *Answers: a:* 4.2×10^6 *L; b: 2.9 hour; c: 4515 kg/day; e: 0.97* $\frac{\text{lb BOD}_5}{\text{lb MLVSS}\times\text{day}}$*; f: 4 days*

7. *(14 pts)* Textbook: 11.16. **Assume that MLVSS = 0.6 of MLSS.**
   Answer: 0.33 $\frac{\text{lb BOD}_5}{\text{lb MLVSS}\times\text{day}}$