Problem Set 8

CEEG 340–Introduction to Environmental Engineering
Instructor: Deborah Sills

Due Date

5pm on Friday 4 November, 2019

Learning Outcomes

1. Analyze and evaluate results from BOD tests and theoretical oxygen demand calculations.
2. Apply mass balances and reactor theory principles to model oxygen demand in the environment.
3. Apply mass balance and reactor modeling to calculate dissolved oxygen concentrations in engineered and natural systems.

Problems

1. *(10 pts)* **BOD:** The organic concentration in a water sample, measured as BOD_u is 4 mg/L. If the BOD reaction rate coefficient is 0.3 day^{-1}, what will be the concentration of organic matter remaining at the end of 5 days? How much oxygen will be used in this period to oxidize the waste?

2. *(20 pts)* **ThOD & BOD from a previous exam:** Suppose you add 150 milligrams of the artificial sweetner aspartame ($C_{14}H_{18}O_5N_2$) to a cup of coffee (volume = 150 mL):

   (a) What is the theoretical oxygen demand (ThOD) of the coffee in units of mg/L (assume that all of the oxygen demand comes from the sweetner)? Note that for NThOD, each mole of nitrogen in aspartame is converted to one mole of ammonium, NH_4, without exerting oxygen demand. Ammonium, NH_4, is then oxidized (and this reaction exerts oxygen demand) based on the equation covered in lecture on Wednesday, 10/30.

   (b) If the aspartame is 85% biodegradable, and 1.5 mL of the coffee with a dissolved oxygen (D.O.) of 5 mg/L is diluted to 300 mL with dilution water containing 10 mg/L of D.O. (and zero BOD), what will the D.O. level be in a stoppered BOD test bottle after 5 days (assume that k = 0.25 day^{-1} at 20 ^{0}C)?

3. *(15 pts)* **BOD approximation:** A water sample has a BOD_5 of 10 mg/L, and contains 2 mg/L NH_3-N (before dilution). The sample was diluted by ten with dilution water and put in a BOD bottle. Initial dissolved oxygen concentration in the BOD bottle was 8 mg/L. Assume the sample was typical domestic sewage (i.e., assume that $BOD_5 = \frac{2}{3}BOD_u$, or that k = 0.2-0.3 day^{-1}). If the bottle was left sealed for a very long time what was the final DO in the BOD bottle? *(Answer: Values between 5 and 6 mg/L are acceptable.)*

4. *(10 pts)* **Reactor Modeling and BOD:** For modeling purposes we need to determine the BOD decay rate coefficient, k, for a river. An experiment was conducted in which two sample were taken from the river at two points separated by a distance of 1 kilometer, and 5-day BOD tests were conducted with both samples in the laboratory. The sample drawn from Point A (upstream) has a $BOD_5 = 7.2$ mg/L. The sample drawn from Point B (downstream) has a $BOD_5 = 3.9$ mg/L. The river exhibits plug flow behavior (i.e., can be modeled as a plug flow reactor), has an average cross-sectional area of 10 m^2, and a volumetric flow rate of 100 $\frac{m^3}{h}$ Determine the "river" first-order BOD decay rate coefficient, k_r.

5. *(10 pts)* **Reactor Modeling and BOD:** The town of Pittsburgh discharges 0.126 $\frac{m^3}{s}$ of treated wastewater into Cherry Creek. The BOD_5 of the wastewater is 34 $\frac{mg}{L}$. Cherry Creek has flowrate of 0.126 $\frac{m^3}{s}$. Upstream of the the wastewater discharge, the BOD_5 is 1.2 mg/L. The BOD rate constants k are 0.222 d^{-1} and 0.090 d^{-1} for the wastewater and the creek, respectively. The temperatures of both the creek and the municipal wastewater are 20 ^{0}C. Calculate the ultimate BOD (L_0, or BOD_u) after mixing.

6. *(10 pts)* **Temperature Effects:** A BOD test is performed on an undiluted sample at 20 ^{0}C and 35 ^{0}C. BOD_5 at 20 ^{0}C was 4.15 mg/L. BOD_5 at 35 ^{0}C was 6.56 mg/L. From this data determine the BOD_u ($BOD_u = L_0$) of the sample. Assume that nitrification was inhibited and that the temperature correction factor, $\Theta = 1.05$.

7. *(25 pts)* **Reactor Modeling and BOD:** A meat processing wastewater containing 2100 $\frac{g}{m^3}$ BOD_5 (at 20^{0}C test conditions) is to be discharged to a stream. The minimum stream flow rate (95 $\frac{m^3}{s}$) occurs in January when the water temperature is 6^{0}C. And the maximum stream flow rate (175 $\frac{m^3}{s}$)occurs in July when the water temperature is 26^{0}C. If the maximum in-stream BOD_5 value allowed is 0.5 $\frac{g}{m^3}$ at ambient temperatures, determine the necessary extent of treatment (i.e. the required % removal of BOD) for a wastewater flow of 0.2 $\frac{m^3}{s}$. Assume the reaction rate constant is 0.2 d^{-1} at 20^{0}C, the temperature coefficient, $\Theta = 1.05$, and the upstream BOD_5 is negligible. *(Answer:Necessary treatment required: 82% BOD removal)*