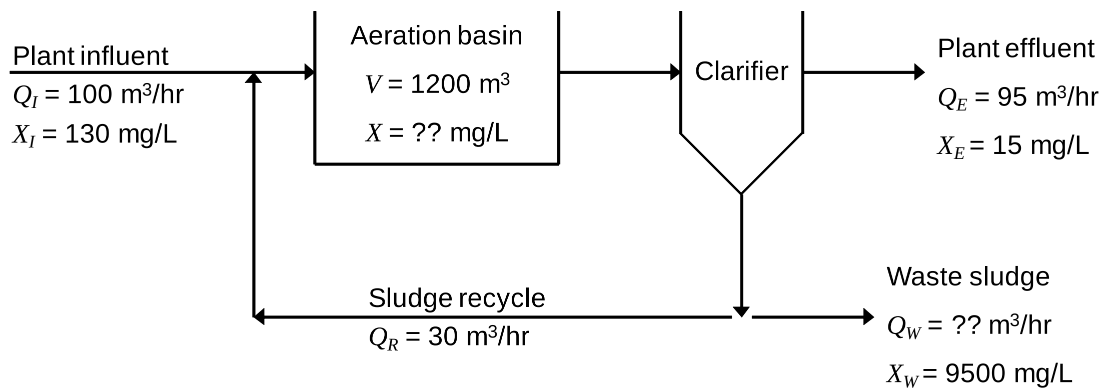
ENV 4001: Environmental Systems Engineering

Spring 2012 | University of South Florida
Problem set #2 | Civil & Environmental Eng.
Finish by Wed., Feb. 1, 2012 | Prof. J.A. Cunningham

This problem set will not be collected or graded. Your reward for completing this problem set is that it is essential for learning the course material and passing the quizzes and final exam.

1. Municipal wastewater (sewage) is usually treated by a method called "activated sludge." We'll learn more about that later in the semester. Below is a schematic diagram that shows the process.



The *aeration basin* is a completely-mixed flow reactor (CMFR) where the sewage is degraded by bacteria. It has a high concentration of suspended solids; we use the symbol X to indicate the concentration of suspended solids in the aeration basin. Because we don't want to release a lot of suspended solids into the environment, the effluent from the aeration basin goes to a *clarifier*. In the clarifier, the suspended solids settle to the bottom under the influence of gravity. Therefore, the plant effluent that comes out of the top of the clarifier has a low concentration of suspended solids (denoted X_E). The sludge that comes out the bottom of the clarifier has a very high concentration of suspended solids. A fraction of the sludge is recycled to the aeration basin, and the remainder is disposed of as waste sludge. The waste sludge has a flow rate Q_W and a suspended solids concentration X_W.

For the purposes of this problem, you may assume that all the streams have the same density, $\rho = 1000\ kg/m^3$. (In fact the sludge density is probably higher, but we'll ignore that.) You may also assume that the system is at steady state, and that the values of V, Q_I, Q_E, Q_R, X_I, X_W, and X_E are all as indicated on the figure.

continued →

Problem 1, continued:

(a) What is the flow rate of the waste sludge stream, Q_W?
(b) What is the concentration of suspended solids exiting the aeration basin, X?
(c) What is the rate of production of solids within the aeration basin, in units of kg/hr? (This is how fast the bacteria grow in the aeration basin.)

Hint: You can answer all of these by performing the proper material balances around the proper control volumes. In my opinion, part (b) is the trickiest because it is not obvious what control volume to use.

2. Answer problem 4.2 in your text book. Note that the figure does not match the text. Use the values given in the figure (i.e., Q_d = 1.000 L/min, not 1,000 L/min).

3. Answer problem 4.4 in your text book.

4. (a) A lagoon for treating sewage has a surface area of 10 ha and a depth of 1 m. It processes 8640 m^3/d of sewage, which contains 100 mg/L of BOD. (Note: BOD is a measure of how much nasty stuff is in the sewage…we'll cover BOD in more detail later.) The effluent from the lagoon should not exceed 20 mg/L of BOD. Assuming that the lagoon is well mixed, what reaction rate coefficient must be achieved in order to meet the effluent standard? You may assume first-order kinetics. Be sure to report the units on the rate coefficient.
   (b) Now imagine that, instead of one lagoon with surface area 10 ha, you have two lagoons each with surface area 5 ha. Sewage is treated by the two lagoons in series, i.e., first through one lagoon, then through the other. The effluent from the second lagoon must not exceed 20 mg/L. Now what reaction rate coefficient must be achieved? (You may assume the same rate coefficient applies in both lagoons.)
   (c) Still consider that you have the two lagoons in series, as you had in part (b). Still consider that the two lagoons are treating 8640 m^3/d of sewage with an influent concentration of 100 mg/L BOD. However, now use your reaction rate constant from part (a). What will be the effluent concentration from the second lagoon?
   (d) Compare your answer in part (c) to the effluent standard of 20 mg/L that you achieved with the single lagoon in part (a). Which system is more efficient: a single lagoon with a surface area of 10 ha, or two lagoons in series with areas of 5 ha each? One might expect the two systems to be equally efficient – after all, the total surface area and the total residence time is the same in each case – so how do you explain the fact that one system is more efficient than the other?

5. What reactor volume is required for a CMFR to achieve 95% efficiency assuming a flow rate of 14 m^3/d and a first-order reaction rate constant of 0.05 d^{-1}? You may assume steady state. What reactor volume is required for a PFR to achieve 95% efficiency under the same conditions? Which one requires a larger reactor volume? Why?

6. Answer problem 4-12 in your text book. What assumption must you make about the river to solve this problem?

7. Radon in people's basements is a problem in some areas of the US. (Not in Florida, because we don't have basements!) Consider a 90-m^3 basement that is found to be contaminated with radon; the radon is coming from the ground through the floor drains. The concentration of radon in the room is 1500 Bq/m^3. Assume that the air in the room is well mixed, and that radon undergoes first-order decay with a rate constant of 2.09×10^{-6} s^{-1}. If the source of the radon is closed off, and the room is ventilated with clean (radon-free) air at a rate of 0.14 m^3/s, how long will it take to lower the radon concentration to an acceptable level of 150 Bq/m^3?