ENV 4417: WATER QUALITY & TREATMENT

Fall 2015 | University of South Florida
Problem set #7 | Civil & Environmental Eng.
Due Thursday, Nov. 19 | Prof. J. A. Cunningham

1. (10 pts) Consider the removal of phosphorus from wastewater by chemical precipitation. Calculate the theoretical mass ratio required for each of the three common coagulants alum, ferric chloride, and lime. In other words, how many kg of alum would be required per kg of P to be removed? How many kg of ferric would be required per kg of P to be removed? How many kg of lime? For alum, assume a molecular formula $Al_2(SO_4)_3 \bullet 14H_2O$. For ferric chloride use $FeCl_3$, and for lime use CaO rather than $Ca(OH)_2$.

2. (20 pts) Answer problems 14.21 and 14.22 in your text book.

3. (40 pts) *Based on a problem from* *Water and Wastewater Engineering: Design, Principles, and Practice*, *by Mackenzie L Davis*
   Imagine that your consulting firm is designing an A^2O process for removal of BOD, nitrogen, and P from wastewater during secondary treatment. Your colleagues have already completed part of the design, including the aerobic reactor. You are now trying to figure out if the system will allow you to meet your phosphorus permit requirement (1.0 mg/L TP), or if you will have to add some chemical coagulant for P removal. Here is what you already know about the system based on what you designed already:
   - influent design flow rate = Q = 90,000 m^3/d
   - RAS flow rate = 0.6 Q, recycled back to the anaerobic stage
   - nitrate concentration exiting the aerobic stage = 6.0 mg/L as N
   - nitrate recycle rate from aerobic stage to anoxic stage = 0.8 Q
   - BOD_5 concentration coming from primary treatment = 138 mg/L, of which 80 mg/L can be classified as "readily biodegradable oxygen demand" or RBOD

   a) Perform a material balance around the anaerobic reactor for the mass of nitrate. Assume that there is no nitrate in the stream that comes from primary settling, because all the nitrogen coming from primary settling is in the form of ammonium. However, some nitrate comes in the RAS. Assume that no denitrification occurs in this reactor (even though some probably does). Use your material balance to estimate the concentration of nitrate leaving the anaerobic stage and going to the anoxic stage.

problem 3 continues →

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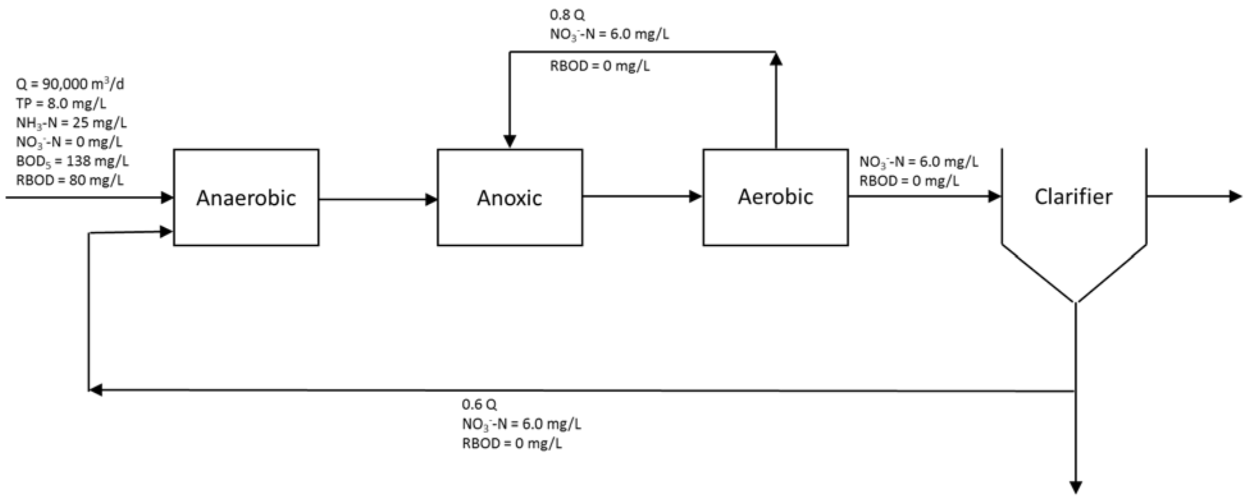

b) Perform a material balance around the anaerobic reactor for the mass of RBOD. Assume that there is no RBOD in the RAS (because it was all used up in the aerobic stage). Use your material balance to calculate the concentration of RBOD leaving the anaerobic stage and going to the anoxic stage. Hint: there are no sources or sinks of RBOD in the anaerobic reactor; the RBOD changes form (e.g., to acetate), but there is no oxygen, so none of the BOD or RBOD can be removed.

c) In the anoxic stage, assume that all the NO_3^- is denitrified to N_2, and that 6.6 mg of RBOD are required per mg of NO_3^--N for denitrification. Perform a material balance around the anoxic reactor for the mass of RBOD. There is no RBOD in the nitrate recycle stream. What concentration of RBOD exits the anoxic stage and goes to the aerobic reactor?

d) From your answer to part (c), calculate the rate at which RBOD enters the aerobic reactor, in units of kg/d. Hint: make sure you are tracking the flow rates in all the streams.

e) In the aerobic reactor, phosphorus-accumulating organisms (PAOs) metabolize the RBOD and grow. When that happens, they assimilate a lot of the P. Assume that 1 kg of P is assimilated per 10 kg of RBOD metabolized. At what rate (kg/d) is P removed from the wastewater in the aerobic reactor?

f) Perform a material balance for the mass of P in the wastewater. Use a control volume of the entire secondary treatment system. There should be 1 stream flowing in to your control volume (from primary treatment) and there should be 2 streams flowing out of your control volume (the treated effluent and the waste activated sludge). From your material balance, estimate the concentration of P (mg/L) exiting the system in the treated effluent.

g) What do you think about the addition of a chemical coagulant like alum or ferric chloride to remove phosphorus? Is it necessary, or can your A^2O process meet the permit requirement (1.0 mg/L as P) without coagulant? Discuss briefly (a sentence or two).

4. (15 pts) A stream with 3% solids (by mass) flows to a thickener at a rate of 1000 L/d. The thickened sludge has 90% solids recovery and is 30% solids by mass. For each of the three streams in the system (influent stream, thickened sludge, and effluent liquid stream), find the volumetric flow rate in L/d, the concentration of solids in mg/L, and the density of the stream in g/L. You can assume that "pure" water has a density of 999 g/L and that dry solids have a density of 2500 g/L.

5. (15 pts) Answer problem 13.4 in your text.

I really wanted to cover aerobic digestion and anaerobic digestion, and we will cover these in course lectures, but I don't think we have time to cover them in course lecture *and* put them on a homework assignment. I will cover digestion in class on Nov 17 and Nov 19, but this homework assignment is due on Nov 19, so I do not want to put digestion problems on the homework assignment.