**1.85 WATER AND WASTEWATER TREATMENT ENGINEERING**
FINAL EXAM
DECEMBER 20, 2005

This is an open-book exam. You are free to use your textbook, lecture notes, homework, and other sources other than the internet.

1.   (12 points)
Fish generate wastewater too! Aquariums need to be equipped with filters to remove fish wastes and uneaten fish food from the water. One such design is the under-gravel filter, illustrated schematically below.
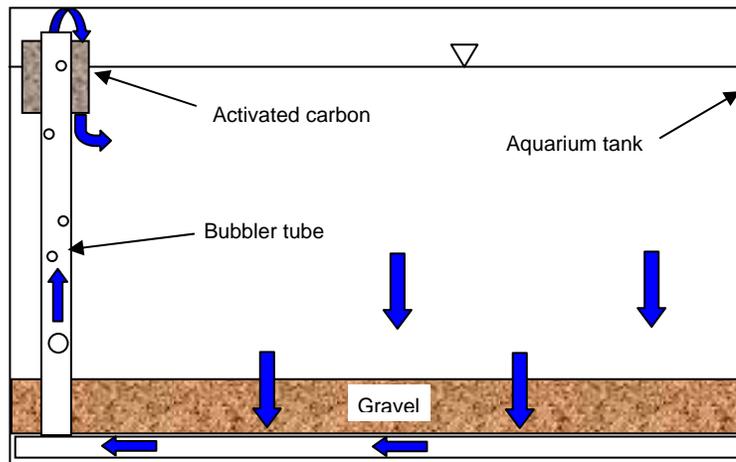

The filter consists of a plastic plate that covers the floor of the aquarium and creates an open space beneath the gravel for water to flow to the bubbler tube. Air is pumped into the bottom of the bubbler tube, and the rising air bubbles entrain water and pump the water upwards. The water bubbles out of the top of the tube, drops into a plastic container filled with activated carbon, and then flows into the aquarium. The flow of water up and out of the bubbler tube causes water to draw from the main part of the tank into and through the bottom gravel and then along the tank bottom to the bubbler tube.

Identify two major treatment functions at work in the aquarium water treatment system and briefly describe how they function.

2. (12 points)

Filamentous bacteria that cause sludge foaming in activated sludge treatment systems differ from the desirable floc-forming bacteria in several aspects of their metabolism. First, filamentous bacteria have different growth curves than floc-forming bacteria as shown in the figure below. Second, filamentous bacteria use only oxygen as an electron acceptor and cannot use nitrate for that function; floc-forming bacteria can use either oxygen or nitrate as electron acceptors. Third, filamentous bacteria cannot store polyphosphates or use acetate for growth as can some floc-forming bacteria.
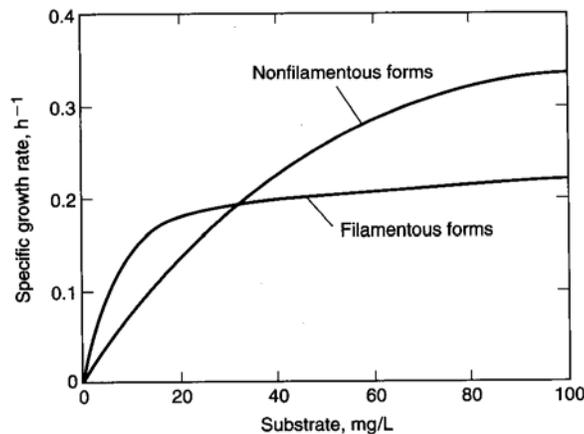
Different designs have used one or more of these characteristics to create "selectors" to favor floc-forming bacteria over filamentous bacteria in AST systems. The selector is typically created in one or more tanks upstream of the aeration tank as shown in the schematic below. The purpose of the selector is to suppress filamentous bacteria growth and thereby control foaming sludge.
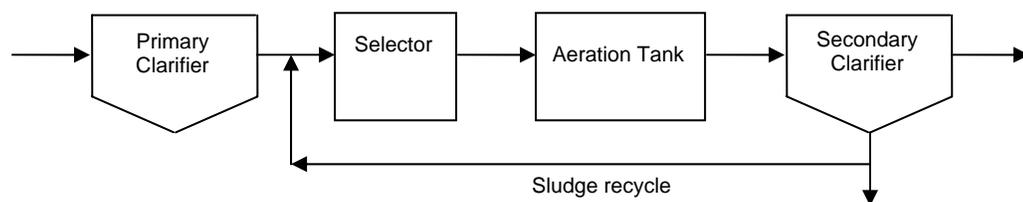
Suggest conditions that could be created in a selector to achieve the design goal of favoring floc-forming bacteria over filamentous bacteria.

3. (8 points)
Parkin and Owen (1986) report the following parameter values for anaerobic digestion of primary treatment sludge:

K_s = half-saturation constant = 1.8 $(1.112^{(T-35)})$ [g COD/L];
μ_{max} = maximum specific growth rate = 0.27 $(1.035^{(T-35)})$ [day^{-1}];
k = maximum specific substrate use rate = 6.67 $(1.035^{(T-35)})$ [day^{-1}];
k_e = endogenous respiration rate = 0.03 $(1.035^{(T-35)})$ [day^{-1}];
Y = cell yield = 0.04 [g VSS/g COD];
T = temperature [°C]

If the sludge flow rate into the tank were doubled and simultaneously the temperature dropped from 35°C to 20°C, by what ratio would the factor of safety decrease?

4. (8 points)
The operations staff at a sewage treatment plant has decided to reduce the SRT of their activated sludge process from 6 days to 3 days by increasing the recycle rate. The goal is to reduce the oxygen requirement. You have been called in as an expert to give a qualitative assessment of this plan.

  a. Will the oxygen requirement actually be reduced?
  b. Will the MLVSS increase, decrease or stay about the same?
  c. Will the sludge settling characteristics improve, stay about the same, or worsen?
  d. Will the effluent BOD concentration increase, decrease, or stay about the same?

Part II – Short-answer Questions (5 points each, 60 points total)
The following are intended to be answerable with a few sentences or a simple sketch.

5. From the standpoint of the overall waste treatment process, is a sequencing batch reactor more like a plug-flow reactor or a fully-mixed tank, and why?

6. The wastewater treatment plant for a small town is heavy overloaded with respect to both the wastewater flow and the solids load. The plant consists of headworks, a primary clarifier, an aeration tank, and a secondary clarifier. Suggest a measure or measures that could be implemented quickly and which would allow the plant to achieve better treatment.

7. What is the difference between an anaerobic reactor and an anoxic reactor?

8. Activated sludge systems are often designed with long, narrow aeration tanks to approximate plug flow within the tank. An existing AST tank is proposed to be modified by turning the aerators off along a length of the aeration tank. The operators hope to improve nitrogen removal using this technique. Do you think this will work? Why or why not?

9. The concentration of mixed-liquor suspended solids (MLSS) is often taken as the concentration of active biomass (represented by the variable X in the AST modeling equations). What are at least two shortcomings to the assumption that X = MLSS?

10. At solids retention times of greater than about 8 days, settling of activated sludge becomes more problematic. Give at least two reasons for this.

11. Why is control of turbidity considered important for disinfection of drinking water?

12. One method to control sludge bulking by filamentous bacteria in activated sludge systems is to segregate the floating sludge ("skimmings") from the secondary clarifier and keep those skimmings from being recycled to the aeration tank as part of the recycled activated sludge. How does this method reduce potential for sludge bulking?

13. A wastewater sample is being analyzed to determine its BOD content. The sample is diluted in order to perform the test: 295 mL of distilled water are added to 5 mL of sample to fill the 300 mL BOD bottle. The bottle has an initial dissolved oxygen concentration of 7.9 mg/L. After incubating 5 days, the dissolved oxygen concentration is 4.5 mg/L.
    a. What is the 5-day BOD of the wastewater?
    b. The deoxygenation rate constant, k_1, is 0.013 day^{-1}. What is the ultimate BOD of the wastewater?

14. An engineer has proposed to add coagulants to improve the Type 1 solids removal in the clarification zone of a sludge thickener and thereby increase the overall solids removal. Is this a good idea? Why or why not?

15. Short-circuiting is a greater concern in disinfection systems when 99.99% removal is the goal than when 90% removal is the goal. Explain why short-circuiting is more problematic when greater removal is sought.

16. An adequate chlorine concentration for disinfection is often achieved prior to the chlorine "breakpoint." Why then is the breakpoint concentration used rather than a lesser concentration?

Part III – Optional Multiple-Choice Question (0 points)

17. For a final exam for 1.85, would you have rather had:

   a. This three-hour final
   b. This final as a take-home exam that would have been handed out on Friday, December 2 and due on Friday December 9.
   c. This final as a take-home exam that would have been handed out on Monday December 5 and due on Monday December 12.
   d. All of the above.
   e. Sorry, "none of the above" is not a choice.