CEE 483, Winter 2009, HW#5

1. An inside-out hollow-fiber membrane system is operated with a crossflow configuration. Each module contains 10,000 fibers that have an inside diameter of 0.9 mm and a length of 1.2 m. Calculate the following:

   (a) The feed flow necessary to achieve a crossflow velocity of 1 m/s at the entrance to the module;

   (b) The permeate flow rate if the system maintains an average permeate flux of 75 L/m^2-h;

   (c) The crossflow velocity at the exit of the module;

   (d) The ratio of the crossflow velocity at the entrance of the module to the flow velocity toward the membrane surface;

   (e) The ratio of the permeate flow rate to the feed flow rate (i.e., the recovery).

2. A microfiltration membrane with 0.2-μm pores is tested with clean water as the feed, yielding a flux of 650 L/m^2-h (LMH) at 23^{o}C when the transmembrane pressure (TMP) is 0.69 atm.

   (a) Estimate what the specific flux (flux/TMP) would be at 20°C. Assume that the only effect of temperature is to alter the water's viscosity;

   (b) Calculate the membrane resistance, in m^{-1};

   (c) When the membrane is used in a full-scale system treating water at 20°C, the specific flux corresponds to the clean-water value when the membrane is first put into service. Just before the membrane is backwashed, the flux is 95 LMH at a TMP 1.0 atm, and after backwashing, the flux is 120 LMH at a TMP of 0.45 atm. By comparing the membrane performance when it is clean with its performance after backwashing, estimate the resistance attributable to irreversible fouling. Make a similar comparison between the performance before and after backwashing to estimate the resistance caused by reversible fouling.

3. A new membrane plant is being designed. The expected peak water demands are 190,000 m^3/d during summer and 136,000 m^3/d during winter. The minimum temperature of the source water is expected to be 4°C in winter and 17°C in summer. If a membrane plant capable of operating at 80 LMH during the summer is to be built, what is the required membrane area? Which season will govern the size of the plant?

4. A water source is at pH 7.4 and has alkalinity and Ca^{2+} concentrations of 1.1 x 10^{-3} equiv/L and 85 mg/L, respectively.

   (a) Is $CaCO_3$(*s*) undersaturated, saturated, or supersaturated in the solution?

(b) What is the minimum (stoichiometric) dosage of lime (mol/L) needed to convert all the carbonate species to CO_3^{2-} (*i.e.*, if the OH^- from the lime could be forced to react exclusively with carbonate species)?

(c) If the lime dosage computed in part *b* were added and the solution then reached equilibrium with $CaCO_3(s)$, how much solid would precipitate, in mg/L? Assume that the approximation that all the carbonate species in the original solution are converted to CO_3^{2-} is acceptable both before and after the precipitation reaction occurs.

5. A drinking water at pH 6.7 has alkalinity of 5.0×10^{-4} equiv/L. The water comes into contact with and equilibrates with malachite ($Cu_2(OH)_2CO_3(s)$) and cerrusite ($PbCO_3(s)$), both of which have formed on pipe surfaces due to corrosion. The solubility products of these two solids are $10^{-33.2}$ and $10^{-13.13}$, respectively.

   (a) Assuming that the interactions between the solution and the solids lead to release of Cu^{2+} and Pb^{2+}, but do not release enough CO_3^{2-} or OH^- to alter the alkalinity or pH of the water, compute the concentrations of Cu^{2+} and Pb^{2+} that would be found in the water downstream of the corroded pipes.

   (b) Would either of these concentrations cause the water to exceed the Action Level under the Lead and Copper Rule? If so, how much would the pH have to be increased to cause the water to be in compliance with the rule?