CE 474/574 - Unit Operations in Environmental Engineering

Design Assignment 5. 2014

Hardness Removal for the Drain, OR Public Water Supply

A stumbling block has occurred in Drain. The city council is balking at the price of the flocculators, clarifiers and filters to meet LT-1 for a surface water supply. The council has insisted that Sal Monella provide them with any feasible alternative. After consulting with a regulatory specialist and hydrologists, Monella has learned that deep groundwater does *not* need to be filtered to meet the new standards (it merely must be chlorinated). Geological surveys indicate there is a fairly productive aquifer about 200 feet below Drain, but it is in a limestone formation and has significant hardness. The U.S.G.S. indicates the water from this formation will have the following composition:

Constituent	Concentration
pH	7.3
Total alkalinity	160 mg/L as $CaCO_3$
Total hardness	165 mg/L as $CaCO_3$
Calcium hardness	150 mg/L as $CaCO_3$

Because this water is so hard, Mr. Monella wants you to design a hardness removal system that would bring the total hardness down to 75 mg/L as $CaCO_3$. Obviously you want to keep this system as simple and cheap as possible, so do only what is necessary to achieve this goal. For now, *don't* worry about designing the clarifier for the system; you can assume your prior design of a clarifier is pretty close to what would be needed here. (The net savings of using groundwater will come from not needing a flocculator or a filter gallery). *For some extra credit include a recarbonation step*, following the guidance below.

Here are a few tips to guide you with respect to the chemistry.

- The table above gives you everything you need to know about the composition of the water to follow the basic design principles we reviewed in class.

- You can get the bicarbonate concentration from the alkalinity from a simple consideration of carbonate chemistry, as we discussed in class and as outlined in the supplemental synopsis (on the web page). You can then calculate initial $[CO_3^{2-}]$.

- Likewise, you can find the raw-water concentration of $H_2CO_3^*$ (= $[CO_2]$ as it is denoted in the text example of lime requirement) from a simple calculation and the data given above. NOTE: This is deep groundwater and the carbonic acid is NOT in equilibrium with the atmosphere. Therefore, do NOT assume it is just 10^{-5} mol/L. Calculate it.

- Remember that carbonic acid is **diprotic**, hence you multiply the concentration by 2 to get equivalents per liter for use in the dosage calculation.

· Don't add any chemicals you don't need.

· **Optional for 2 extra points:** Include a final recarbonation step that returns the water to pH 7.3. At pH 7.3 all of the final alkalinity can be assumed to be in the form of [HCO3-]. (And remember that adding CO_2 does not add or remove alkalinity, so that makes it easier.) You can thus determine the recarbonation-CO_2 dose from the final concentration of [H_2CO_3*] at pH 7.3 (calculate using [HCO3-] and the pH = 7.3) plus the additional CO_2 needed to convert the **residual** CO_3^{2-} (final "high pH" CO_3^{2-}) into HCO_3^-.

$$\text{Total } CO_2 \text{ Dose} = [H_2CO_3^*]_{\text{Final-pH}} + [CO3\text{-}]_{\text{High-pH}}$$

Deliverables:

1. Determine the dose of lime needed in mg/L and also in lb/day for the design flow used in the previous assignment.
2. Calculate the final composition of the water after the softening, including the pH, but *before* recarbonating the water. Remember that the bicarbonate remaining is the amount you started with minus the amount of carbonate hardness you removed minus the amount of bicarbonate you converted to residual carbonate. Also, when calculating the pH, remember to switch [CO_3^{2-}] into mol/L units from eq/L

   OPTIONAL (+2 POINTS)

3. Report the dose of $C0_2$ needed for recarbonation in mg/L and also in lb/day for the design flow rate.
4. Calculate the final composition of the water after the recarbonation step that returns the pH to 7.3.