1.101 Introduction to Civil and Environmental Engineering Design
Laboratory Exercises, Sept 21, 22

Design Curve for acid neutralization by dissolution of calcium carbonate;
Flow/pressure regulation for treatment device output

A preliminary suggestion: Because the pH sensor system that you built in the first lab exercise will be used throughout the next phases of your treatment project, you may wish to create a simple means of quickly converting electrode voltage to pH—this might be a regression equation implemented on a handheld calculator, or perhaps a graph or even a table on paper.

In this second exercise, we will consider the neutralization of acid by dissolution of a solid, in contrast to addition of an aqueous solution of strong base as we did last week. Addition of base by dissolution of a solid could be a second basis for conceptual design of a neutralization system (the first is, of course, direct addition of NaOH solution in the correct amount).

These two different conceptual designs pose different challenges for the designer. A system that neutralizes acid by adding aqueous base must have a means of injecting the solution of base at the correct rate, which will be as low as zero when the water is turned off, but must be made high enough to fully neutralize water when flow is of the order of a gallon per minute. By contrast, if water is contacted directly with solid base, there may be no need for sophisticated flow measurement, but on the other hand it will be necessary to know at what *rate* the solid material will dissolve when in contact with water, so that your design will meet requirements even at the highest required flow rate.

During this second exercise, we will empirically develop a *design curve* that will be of much assistance in the design process of any system that is based on solid dissolution. The several steps of this exercise include:

1. Pre-washing of calcium carbonate sand. Because the process of pulverizing and sorting the various calcium carbonate materials produces some very fine-textured dust, this dust must be removed prior to testing. When contacted with acidic water, the dust will dissolve very quickly, given its very large surface area. However, a treatment column must function for weeks or months, long after the initial dust has been dissolved. Design curves, to be useful, must be based on calcium carbonate sand from which the dust has been removed. Thus, each material must be pre-washed, using containers of mildly acidic water and mesh bags.

2. The rate of neutralization of water will depend on the surface area of calcium carbonate *relative to* the amount of water in contact with this surface area. We can take advantage of the fact that this ratio is <u>fixed</u> for any given saturated porous medium and particle size. In such a medium, the volume of water is equal to the total bulk volume of medium multiplied by its *porosity,* n. The surface area of solid is calculated from

knowledge of particle size and the total volume of solid, which equals total bulk volume of medium times the quantity (1-n). As an exercise, roughly estimate the water volume to surface area ratio for each of the three calcium carbonate materials when they are saturated with water.

3. For each sample of calcium carbonate sand, use gravity drainage to remove as much wash water from each sample as possible, then quickly place the sample in an open container and add acidic water until the material is saturated.

4. In each sample, measure pH as a function of time, at least until the design requirement of pH 7 is met, and preferably until the pH stops rising. You will need to use a screen in a way that permits the electrode to contact porewater without damaging the pH sensor. REMEMBER, THE SENSOR HAS A VERY THIN <u>GLASS </u>MEMBRANE

5. Estimate the required residence time of water for adequate neutralization in each of the three porous media, and prepare a 'design curve' in which residence time is plotted against particle size. This should be kept in your notebook. <u>Please submit a summary of your residence time findings to the instructors </u>at the end of the lab session. A composite data set will be made available to the entire 1.101 class.

6. For this project, you will be provided with access to a water pipe that supplies mildly acidic water simulating what might be pumped from a well. A pressure gage is provided for measurement of water pressure on the supply side of your device. Even though you have probably not designed your treatment project yet, it will be necessary to have a device that regulates flow and measures water pressure at the outlet side of your treatment device. To get a head start, you should construct this device after completing parts 1-5 above.