Design Assignment 2.
Coagulation & Flocculation of the Drain, OR Public Water Supply

The town of Drain has now addressed its need for chlorination, but the LT-2 rule also requires that the water meet stringent *Cryptosporidium*-removal and turbidity standards. These require filtration. The Elk Creek water supply is normally not very turbid and typically has turbidity less than 5 NTU. If we could rely on such low turbidity, we could probably use direct filtration, i.e., send the raw water directly to a rapid sand filter.

However, experience has shown that high winter and spring flows can lead to episodes of unusual turbidity in this catchment. For example, during the extreme flood conditions of February 1996, turbidity of over 200 NTU was observed in Elk Creek and the citizens of Drain were without a water supply for about a week. Such high turbidity can overwhelm a direct filtration system so it may be more efficient to include a simple coagulation-flocculation-sedimentation system to reduce high turbidity during the annual spring freshet. For this assignment, you have been asked by Mr. Monella to prepare a plan for the first stage of the system: the coagulation regime.

D/DBP Stage 1 Rule: Under the Disinfection/Disinfection By-Product (D/DBP) rule, Stage 1, the USEPA regulates the amount of total organic carbon (TOC) that must be removed from the source water during the coagulation step, according to the following table (Source: http://water.epa.gov/lawsregs/rulesregs/sdwa/stage1/factsheet.cfm) The goal, of course, is to lower the potential for DBR formation.

Required Removal of Total Organic Carbon by Enhanced Coagulation and Enhanced Softening for Subpart H Systems Using Conventional Treatment[1]

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0-60	>60-120	>120[2]
>2.0-4.0	35.0%	25.0%	15.0%
>4.0-8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

Tests have shown that the Elk Creek source water is consistently *below* 2.0 mg/L TOC, although it often approaches this level in the low-flow period of late September. Alkalinity in Elk Creek is always quite low, well below 60 mg/L as $CaCO_3$. In this assignment, you do not have to predict the TOC removal (and no data is currently available anyway.) However, you might want to alert Mr. Monella that such additional treatment criteria *may* be required in the future if either the Creek TOC levels rise or if EPA ules become more stringent.

Coagulation Lab Tests:

A set of jar tests has been completed using both alum ($Al_2(SO_4)_3$ $14.3H_2O$) and ferric sulfate ($Fe_2(SO_4)_3$). To simulate the high-turbidity conditions of the spring freshet, a sample of river water was mixed with river sediments to yield a final turbidity of about 50 NTU. The table below shows the final turbidity observed for each dose of alum of ferric sulfate. The tests were conducted at pH 6.0 (the normal pH of the river water.) The lab reported that preliminary tests indicated an optimal G value in the jars of 30 s^{-1} and all the data below are for test conducted at G = 30 s^{-1}.

	Alum	**Ferric Sulfate**
Dose in mg/L	Final Turbidity in NTU	Final Turbidity in NTU
10	26	17
20	19	12
30	14	7
40	4	5
50	15	14

1. Decide on the optimal dosage of both alum and ferric sulfate. For the flow assumptions already made for Drain, calculate the number of pounds per day of commercially alum and ferric sulfate needed. See data at the end of the assignment.

2. Alum and ferric sulfate both perform best at slightly acidic pH. (Fe salts are usually optimal at pH a bit lower than alum, but Fe salts also have a considerably wider pH range of effectiveness, so the exact pH is not very critical.) Since the pH of the source water is 6.0 and the tests were conducted at 6.0, we will design the system to remain at pH 6.0 (as we did with the chlorination system). Calculate the number of pounds per day of commercial soda ash need per day to maintain pH 6.0 for the optimal alum and ferric sulfate treatments.

3. Design a flash mixer for the coagulant addition using the following suggestions. [At this early stage in the course I am going to keep everyone more or less on a single design track. Later I will start giving you more latitude to make judgments about design choices.]

   Use a baffled cylindrical tank with a turbine mixer with either a 4- or 6-bladed vaned disk. That style of impeller has the greatest power factor, meaning the slowest rotation rate to achieve a given power input.

   The baffled cylindrical tank data given in the book for mixers assume baffle width is 10% of tank diameter, leaving 80% for the impeller. To allow for clearance, assume the impeller diameter is 70% of the tank diameter.

   Use a retention time of 40 s to size the flash mixing tank. Size the tank such that the depth is equal to the radius. (*Radius*, not diameter)

Use the expression $G\ t_{dopt}\ C^{1.46} = 5.9 \times 10^6$ (page 391 in text) to identify the proper value of G for the rapid mixer. For simplicity, you can use the optimal alum concentration for both alum *and* ferric sulfate designs. (The difference in design will be negligible).

Make a sketch of what the mixer looks like and report the following design parameters:

> Depth and diameter of tank

> Impeller diameter

> Power consumption in watts and horsepower

> Rotation rate in rpm (rotations per minute). [**Note**: The rate N obtained from Eq. 13.9b is in units of s^{-1} which is *not* the same as "rotations per sec." N is the "angular rate of rotation" and the conversion is rps = N / pi (N/3.14). To see why this is, look at the definition of the impeller velocity v = ND and compare that to the distance an impeller blade travels in one revolution.]

Present a table of all chemical costs per day for both alum and ferrous sulfate

Information on Chemicals:

	Alum ($Al_2(SO_4)_3$ 14.3H_2O)	**Ferric sulfate (Fe2(SO_4)$_3$)**
Purity	95%	90%
Price/100 lb bag (at individual-bag price)	\$82/bag	\$102/bag