Stock Tank Mixing Spring 2011 Reflection Report 2

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Abstract

The Stock Tank Mixing Spring 2011 team is tasked with improving the current mixing system installed in AguaClara plants. Since the previous reflection report, the Stock Tank Mixing team has continued researching and experimenting with alum and has recently started researching PACl. Some of this research includes analysis of different mixing designs and theories, conduction of an ongoing literature review of documents pertaining to the properties and mixing abilities of both alum and PACl, and the design and testing of a small scale model of a mixing reactor. In addition, our team has been contacting suppliers of PACl with the goal of obtaining some for research and testing as soon as possible.

Keywords: mixing reactor, PACl, alum, mixing properties

Introduction

The Stock Tank Mixing Spring 2011 team has been working to improve the current mixing system in place at AguaClara plants in Honduras. Currently, the operators are dumping coagulant granular into a tank of water and then stir the solution using a PVC tube. Most research since our previously submitted reflection report has been on mixing reactors designed for use with alum. Although we were focusing on designing a mixing system for use with alum, we had assumed that whatever mixing reactor we came up with would also be suited for us with PACl. We were later informed that alum would potentially be phased out for use in AguaClara plants and be replaced with PACl (polyaluminum chloride). After preliminary testing with PACl, we realized that the properties of PACl and alum are very different. These differences in properties drastically changes the reactor designs we were considering and caused some of our research to become irrelevant to our new goal of designing a mixing reactor that will be used for PACl. The primary difference in properties affecting our mixing reactor is that PACl granular material is finer and is less dense than water.

We estimate that PACl granules are, on average, at least one order of magnitude smaller than alum granules. This difference in size means that PACl will tend to dissolve in water much quicker than alum. In addition to this change in size, the density of PACl is lower than the density of water (density of PACl - 0.65 g/cm^3). This means that PACl will tend to float on the surface of the water until it has become wet enough to sink. These properties influence our design objectives and, to that end, we no longer consider the alum mixing reactor we have been working on (the 'double bucket') to be relevant. This is because the downflow water will push the floating granular to the side rather than flow through the granular layers. And additionally, it turned out PACl will easily dissolve after it got contact with water. Therefore the double bucket system, which is a system for dissolution, would not be necessary. It should be noted that although we are discarding the alum mixing reactor, our team gained valuable experience while working on it. Hopefully, the experience gained from the 'double bucket' will allow us to ultimately produce a better design product.

It should also be noted that we had been considering another design for use with alum. This design would have incorporated the use of an upflow mixing system, where the combination of the downward force of gravity and an upward force from pumped water would create a turbulent system that would be conducive to efficient mixing. However, as stated before, we only recently discovered that the properties of PACl would necessitate the formulation of a brand new design for a mixing reactor. Therefore, the information presented in the following sections was obtained with the mindset that alum would be used.

With the use of PACl now in mind, we have begun preliminary work on designing a new reactor better suited to PACl's properties. We have settled on an impeller type design that will incorporate paddles for creating turbulence. Research and design into this mixing reactor has just begun.

Experimental Design

Our proposed alum experiment is shown in Figure 2. bellow

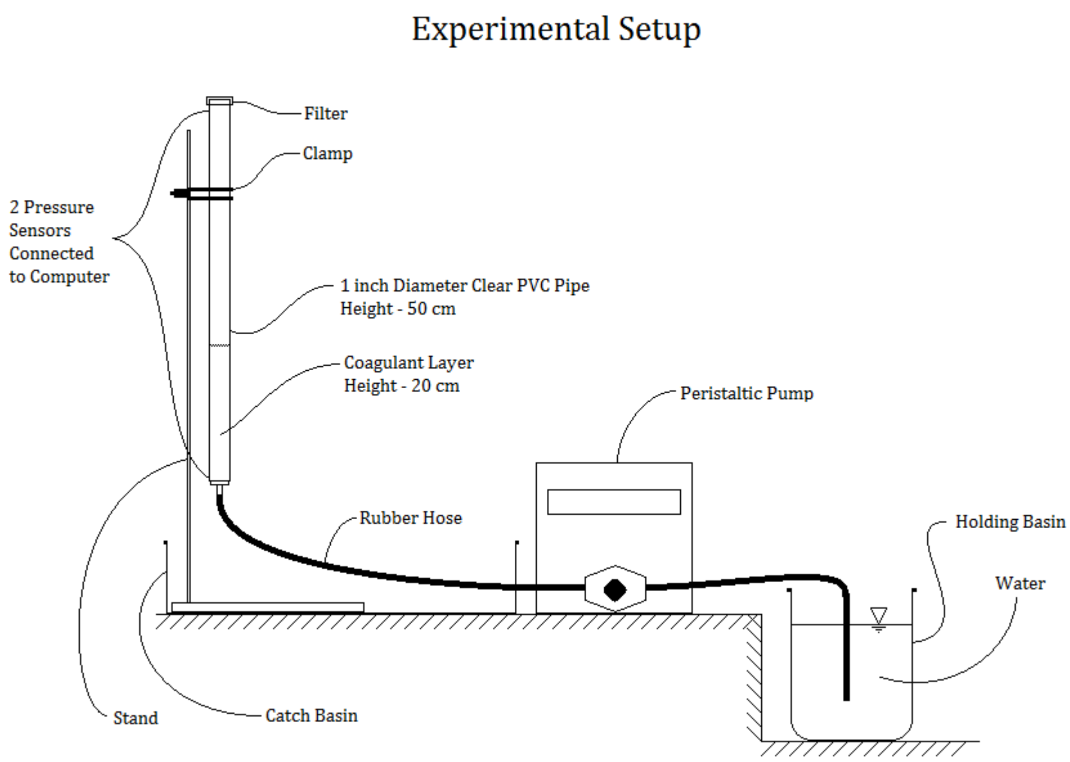

Figure 1. Sketch of the Stock Tank Mixing experiment with 20 cm of alum to find the concentration as a function of time.

The purpose of our first experiment was to test the alum concentration of the solution in the pipe as a function of time using pressure sensors and the process controller given a 50 cm length pipe with a ⅞" inner diameter and 20 cm layer of alum. The experiment was conducted with water flowing up the pipe and a filter was also attached at the top of the pipe to prevent granular alum to flow out of the pipe. The process controller would gather pressure readings at the bottom and the top of the pipe in order to calculate the concentration measurements in the pipe over a measure of time. After this experiment, we would test with different flow rates and different thicknesses in alum.

Since this was our first experimental design and there were no teams we could find doing similar experiments in the past, we have made many assumptions. For example, we assumed that once the granular alum was small enough to flow out through the filter, the solution was saturated.

Results and Discussion

For the experimental design described above, several problems may have caused us to get inaccurate data. These problems are discussed below:

1) The filter design was applied to prevent small granular from exiting the tube. However, the filter turned out to be inapplicable. Since the granular size gets smaller and more granular alum gets washed to the top of the tube, the filter will get clogged by small particles and would eventually form a "filter cake" which greatly increases the head loss through the filter and thus lowering the flow rate. This clogging problem could lead to the failure of the whole experimental system as the dissolution rate decreases with the drop in velocity. Also, the filter idea might not be applicable in a full scale model since it would be hard to get the appropriate type of filters in Honduras.

2) Instead of using a filter, we can determine the flow velocity to keep the granular alum from exiting the top of the tube. We will make an assumption that once the solution flows through this pipe, the solution would have no granular slum. In this experiment variation, the flow velocity would equal to the terminal velocity of the alum particles and then we would experiment with this maximum flow velocity to find the optimum point in which the highest dissolution rate occurs. However, this maximum flow velocity would be hard to calculate, because the concentration (or density) of the solution in the tube constantly changes throughout the experiment which leads to a changing of terminal velocity. We could make an assumption of a constant concentration, but that would make the calculation much more inaccurate.

3) We could determine the gravity head of the solution in the tube by applying a pressure sensor at the bottom of the tube and then calculating the density of the solution as a function of ρ, g and L. (Equation 1)

$$P = \rho g L \qquad \text{(Equation 1)}$$

where,
P - pressure from pressure sensor;

ρ - density of the solution

L - length of tube

However, as there is alum granular in the tube, the density we calculate out of the pressure would not be the density of the solution but of the mixture of the solution and granular suspension. In order to solve this problem, we would need to add anther tube after the mixing tube, in which would be no granular, and measure the pressure in the added tube to calculate the solution density. And the problem with this new tube is that we won't get useful data until the tube is filled up, therefore the density we get will not be the on time density in the mixing tube. Thus, the smaller the added tube is, the more accurate the data. On the other hand, as the tube getting smaller, the head loss due to friction will not be negligible relative to the head loss due to gravity, which would make the calculation inaccurate. Therefore, there is a trade off in the size of the added tube.

We recently discovered that PACl is less dense than water (and alum is denser than water). This property of PACl makes the mixing system we designed for alum inappropriate for PACl, as most of the PACl adding to water will float and will be easily washed out. And we also notice that PACl granular won't sink until after it is wet, which means we cannot use a downflow system without applying a filter. Therefore, the mixing system for PACl would be completely different system from the system for alum. The good news is that PACl showed a relatively higher dissolution rate than alum at same conditions. Thus it is likely that it would be easier to achieve the mixing goal for PACl.

Future Work

Although the team has made progress experimenting with properties with alum, we will start researching and testing with PACl exclusively. In order to do so, the team will conduct research on the properties of PACl and gather new design ideas and start experimenting as soon as possible. Since PACl is much easier to dissolve than alum, the team decided to focus on the 55 gallon drum design instead of designing a pre-mixing apparatus (i.e. double bucket design detailed in Reflection Report 1). We are planning to experiment with different stirrer designs. Once our designs are finished, one member of our team will be in charge of designing this stirrer into the AguaClara system.

Team Reflections

The Stock Tank Mixing team has really seemed to grow as a cohesive group over the past couple months. In addition to meeting for AguaClara related work outside of class, we have had meals together and participated in activities with other teams outside of class. These activities have really helped us work better as a team. Every member on the team has taken a fair share of work to keep the teaming moving smoothly towards our goals. In spite of setbacks, such as discovering that the alum research was largely irrelevant, our team's morale has not suffered greatly. Finally, our sub team leader Jae has maintained contact with Monroe to keep him informed of our activities. This has helped keep our team on the right track. Additionally, Jae is willing to spend much time outside of class preparing for team experiments, etc.