Demo Plant Team

Eric Stucker and Jen Weidman, Spring 2013, 5/2/13

Abstract

The demo plant team is responsible for design, construction, and troubleshooting of the AguaClara Demo Plant. The successful operation of this plant is crucial in order to demonstrate the inner workings of AguaClara plants to students, faculty, staff, community members, business partners, and potential sponsors. This spring semester, our research team has focused on creating one complete demo plant, and fixing issues with that plant, such as an unreliable flocculator and concerns with differences in head. This work included implementing and testing new fittings for the stacked rapid sand filter, conceptualizing and implementing a more efficient way to facilitate plant assembly and startup to those unfamiliar with it, resolving issues with improper coagulant dosing and head loss differences, and properly documenting all aspects of the plant so that future team members new to AguaClara (like us) would have much less difficulty familiarizing themselves with the Demo Plant.We also measured and adjusted plant flow rates to match historical data and ensure smoother operation of the plant, and labeled tanks to further improve ease of operation of the plant. While we did not achieve our goal of fabricating new plants for future teams to use, we documented all the materials present, as well as those we need, and we provided detailed drawings for future construction.

Literature Review:

We did not conduct a formal literature review, but we read the users manual and final reports from the demo plant teams in previous semesters. The links to those reports are provided below. From the most recent manuals, we learned how to best fill and backwash the stacked rapid sand filter (SRSF). We found information about how previous teams fabricated the flocculator on the AguaClara wiki page under demo plant design and construction. More recently, we obtained information from previous demo plant reports on the plant flow rates, coagulant dosing, and raw water turbidity measurements. This will prove useful when measuring flow rates throughout the plant to check tubing lengths for head loss. We also realized what important information about the demo plant was not available or easy to find on the wiki. For example, there does not appear to be much documentation on the SRSF fittings – either what they should look like or how to fabricate them. So we took care to document as much information as possible for the demo plant. The current demo plant user manuals, while useful, are outdated. They pertain to prior designs, so we extracted the applicable information, filled in existing gaps, and updated older information. We also included an assembly guide with the users manual.

2011 Plant Report
Spring 2012 Users' Manual
Spring 2012 Final Report
Summer 2012 Plant Report
Fall 2012 Plant Report

Introduction:

Demonstration plants play a crucial role in educating people about how AguaClara plants work. Instead of simply presenting equations and theory, the plant allows people to see how each aspect works and how the system as a whole effectively treats raw water. AguaClara has utilized demo plants in partner countries and communities, within the Cornell community as an outreach to students, faculty, and alumni, and at off-campus events for outreach as well as funding purposes. The demo plant positively impacts presentations in all of these places, so long as it runs smoothly and works effectively.

The demonstration plant has come a long way over the past few years – previous teams have changed the frame from bulky, heavy, aluminum to light-weight, durable PVC. The full labeled setup can be found in Figure 1.The sedimentation tank, flocculator, and stacked rapid sand filter have also been vastly improved. However, the demo plant still has a long way to go before it is truly ideal. This semester, we aim to improve the demo plant from many angles.

First, we began this semester without even one complete demo plant to work with on campus, as we took the functioning demo plant to Honduras and left it with Agua Para el Pueblo (APP) for presentation purposes. A major concern about the demo plant is also that it is very difficult for team members, and others who have not worked with it much, to assemble. The assembly process can be very confusing and time consuming, which is especially an issue when visiting places off-campus. Additionally, it is difficult to contact the current/most recent demo plant team members while off-campus. We will work to improve the ease of assembly for everyone involved. Finally, it seems like everything from the coagulant constant head tank through the flocculator could be working better, so we are working to improve these issues and innovate the demo plant design.

Methods:

0.1. Stacked Rapid Sand Filter

Early in the semester, we worked with Diana and Owen, who were on the demo plant team over the previous summer and the fall semesters to collect all parts available and learn how to assemble the demo plant. We spoke with both of them about current issues with the plant and what we could think about

Figure 1: Full Setup

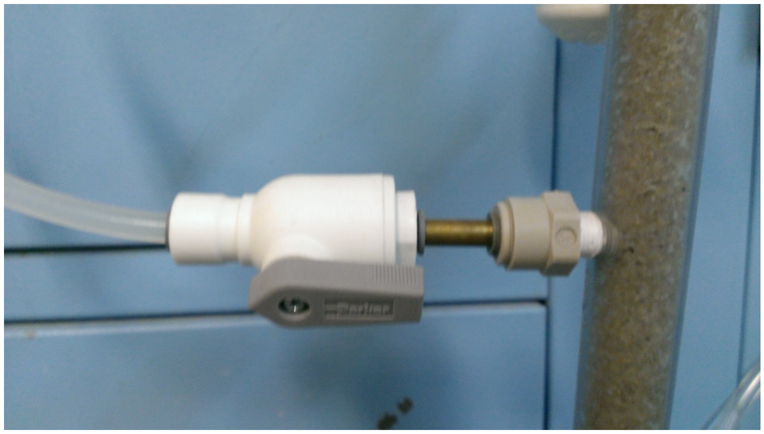

Figure 2: Fitting Close-up-1

doing to address them. This allowed us to assess what was missing from the complete demo plant: fittings for the stacked rapid sand filter. We tracked down information about the SRSF fittings with the help of Paul Charles, and ordered more parts for the fabrication of said parts. However, fabricating these complicated pieces is very difficult, and time intensive for a busy lab technician. So, Paul and Monroe brainstormed and found a new, easier, less expensive way to machine fittings – using a soldering iron to secure a filter to the end of a brass tube, instead of installing springs and undergoing more difficult machining. The part components can be found in the users manual; the brass rods are cut down to size, and then a small piece of the metal mesh filter is soldered onto one end of the tube. Then, Paul drilled into the plastic valves and connectors to widen the opening and insert the brass tubes. Finally, the threaded end of the fittings are wrapped with Teflon tape for a seal, and then can be screwed in to the threaded holes in the SRSF. A close-up view of one of these fittings is shown in Figure 2, and the full filter can be viewed in Figure 3. Once the fittings for the SRSF were complete, we had an entire plant to run. Filling the stacked rapid sand filter consisted of adding water, then sand, to prevent air bubbles from forming within the filter. Sand must be added slowly and carefully, in order to prevent air bubbles and other gaps from forming. This process is detaield in the Users' Manual. We also added a plug for the bottom of the sedimentation tank to prevent water from shooting out, so we could run the entire plant. Over the course of testing the filter, we found that leaving the backwash tube closed prevented reliable flow through the entire system and we found that other clogs in the system may lead to rapid draining of water from the flocculator, reducing its efficiency. These problems will be discussed in the flocculator section.

0.2. Frame

We took apart the entire demo plant to get a better feel for how to assemble it, we introduced May Sharif to the assembly, and we started thinking about how

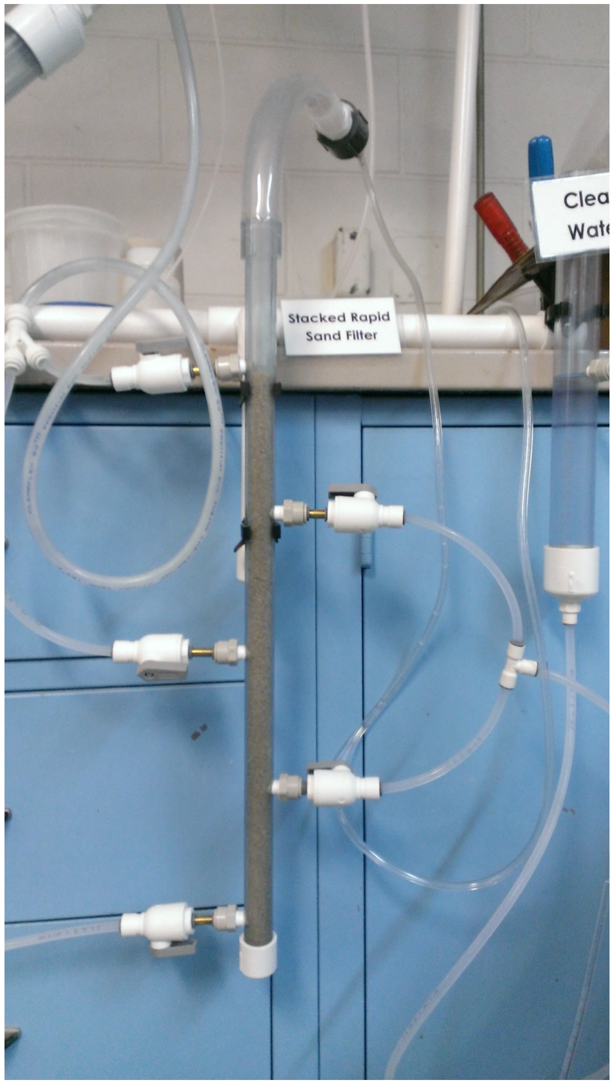

Figure 3: Full Filter-1

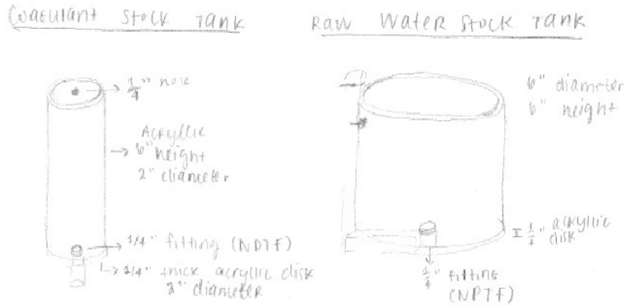

Figure 4: Part of Detailed Drawing

we could facilitate a simpler and less time intensive plant set-up. Additionally, we have recently created a backdrop (Figure 5) which shows how the plant is to be assembled. Upon testing it on Casey, it appeared to be a useful tool that greatly decreased the time needed for assembly for someone unfamiliar with the Demo plant. We also re-labeled the numbering system on the PVC frame for a few reasons: the numbers were quite faded from being written inside of pipe connections, numbers in a different location would be easier to find, and a couple of the numbers were wrong, making the process even more confusing. As for the plant, as a whole, we wanted to take steps to make fabrication of future plants easier so we also took inventory of which parts would require a detailed drawing for the shop, and were unable to find current drawings of these parts. As a result, we hand-sketched detailed drawings of each part needed, in order to help in the machining process, as well as for future documentation. These drawings , an example of which is shown below (Figure 4) have been scanned and saved to our group folder.

0.3. Flocculator

Upon testing the plant, cracks in the flocculator became evident, as it sprung many leaks and could not even fill completely with water. We applied silicone sealant to the bottom of the flocculator, near where it connects to the base a few separate times in order to seal the leaks. Then, we used acrylic glue to attach stabilizing feet to the bottom of the flocculator. The feet were not deemed to be a reliable or aesthetically pleasing design for the flocculator, so they were removed. New flocculators were prepared by Monroe for his trip to San Francisco. These flocculators were threaded on both sides, instead of just the side with a water outlet, which can be seen in Figure 6. The other side of the flocculator was used for a 'foot' which has helped stability, but still left it tilted to one side or otherwise insufficiently supported. Among these new flocculators, we identified a small leak in one of the three. We were advised to not use silicone sealant again to try and fix this leak, and instead have attempted to locate and

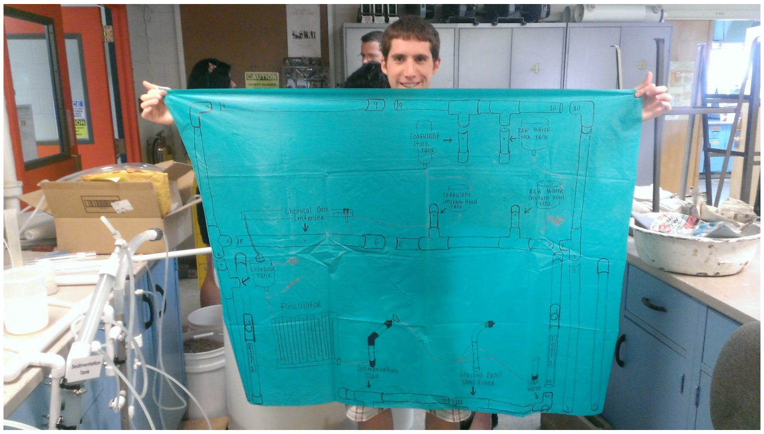

Figure 5: Detailed Backdrop

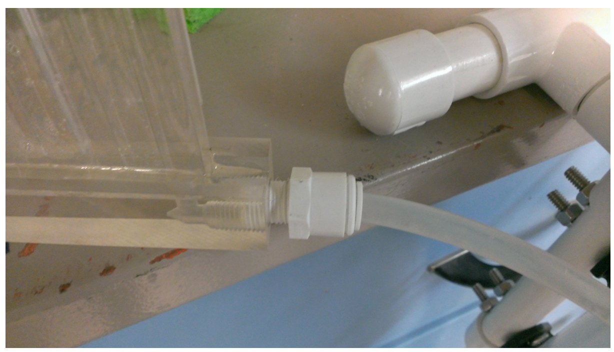

Figure 6: Flocculator Threading

test a polycarbonate, waterproof seal. Another problem with the flocculator is clogging and overflow of water through the tops of the baffles, instead of steady flow through the system. Upon consulting with Professor Lion, it seems as though the problem stems from a buildup/clogging of flocs in the flocculator and the tube connecting it to the sedimentation tank. Similarly, while the sedimentation tank functions very well, the removal of a past floc drain has left the flocs to settle into this aforementioned tube - requiring occasional drainage by opening the bottom of the sedimentation tank, allowing the sludge water to drain out.

0.4. Stock and Constant Head Tanks

We also want to label the plant with the flow rate, and the coagulant constant head tank and raw water stock tank with the associated PACl concentration, turbidity, and flow rate, respectively. In order to do so, we measured the mass of each spoonful added to one liter of water and calculated the values. We also used this mass information to size larger spoons that could be used with the coagulant and clay, so that dosing and mixing are easier to complete. The chemical does controller provided another challenge. The thin tube from the coagulant constant head tank to the chemical dose controller had very high surface tension from the way it was cut, creating bubbles immediately, and preventing water or coagulant to run through. We changed the cut on the end of the tubing from tapered to a straight cut, then filed the ends down to make the tube slightly more narrow so that it would fit into the exits of both the coagulant constant head tank and the doser. The tubing, which was 1/8" in diameter, was filed down on each end to 0.115" and 0.118", but we found only the smaller end was fit for connecting to the coagulant constant head tank. Thus, that side was also distinguished with a small ring of blue electrical tape, as canbe seen on the lower left of Figure 7. We measured flow rates through the plant at several points in order to determine proper tube lengths, with the ultimate goal of zeroing the chemical dose controller so that when the coagulant constant head tank is at steady state, the dose controller entry is level with the water level and there is no flow. We cut the tubing connecting the tank to the plant's frame in order to fix the elevation difference.We also sought out information on plant flow rates and tubing lengths in order to test head losses and evaluate tubing choices in the plant. While we found useful information regarding these flows, the plant's actual flow rates differed greatly over the course of our own experiments. The ideal flow rate for the plant was calculated based on water flow through the SRSF, 11 millimeters per second, and the cross-sectional area of the SRSF, based on the diameter of 13.87 millimeters. Based on the SRSF flow rate, water should flow through the plant at 1.66 mL/second, or about 100 mL/minute. (Q=Afilter*Vbackwash) At this flow rate we found that the Raw Water stock tank must be refilled every 10 minutes per Liter of raw water added. Flow rates in the plant typically ranged from 50 to 75 mL/minute, with occasional outliers. Therefore, the head loss in the raw water tubing was restricting flow; to correct this, we tested the plant's flow rate until we had achieved ideal flow through the plant. In this way, we reduced the tubing length by 6 inches, giving us a new length of 74 inches. We also measured the mass of PACl and clay added to their respective tanks by placing the recommended doses on a scale. These values were recorded and converted to concentations. Furthermore, we ordered new dosing spoons with longer handles, for easier operation. They provide the required doses to each tank with just on scoop. Using all of this data, we were able to properly determine concentrations in the tanks and label them on the plant. Were able to do likewise with the Chemical Dose Controller, labeling the dosing arm according to reflect their corresponding coagulant flow rates. The equations for determing the stock concentratons are shown below:

Plant flow rate = 100mL/minute

Coagulant flow rate = 1mL/minute

Coagulant:Plant flow ratio = 1:100 = 0.01

Coagulant Stock Tank Concentration = 650mg/L

Coagulant Dose = 650mg/L *0.01 = 6.5mg/L

Raw Water Stock Tank Dose/Concentration = 900mg/L

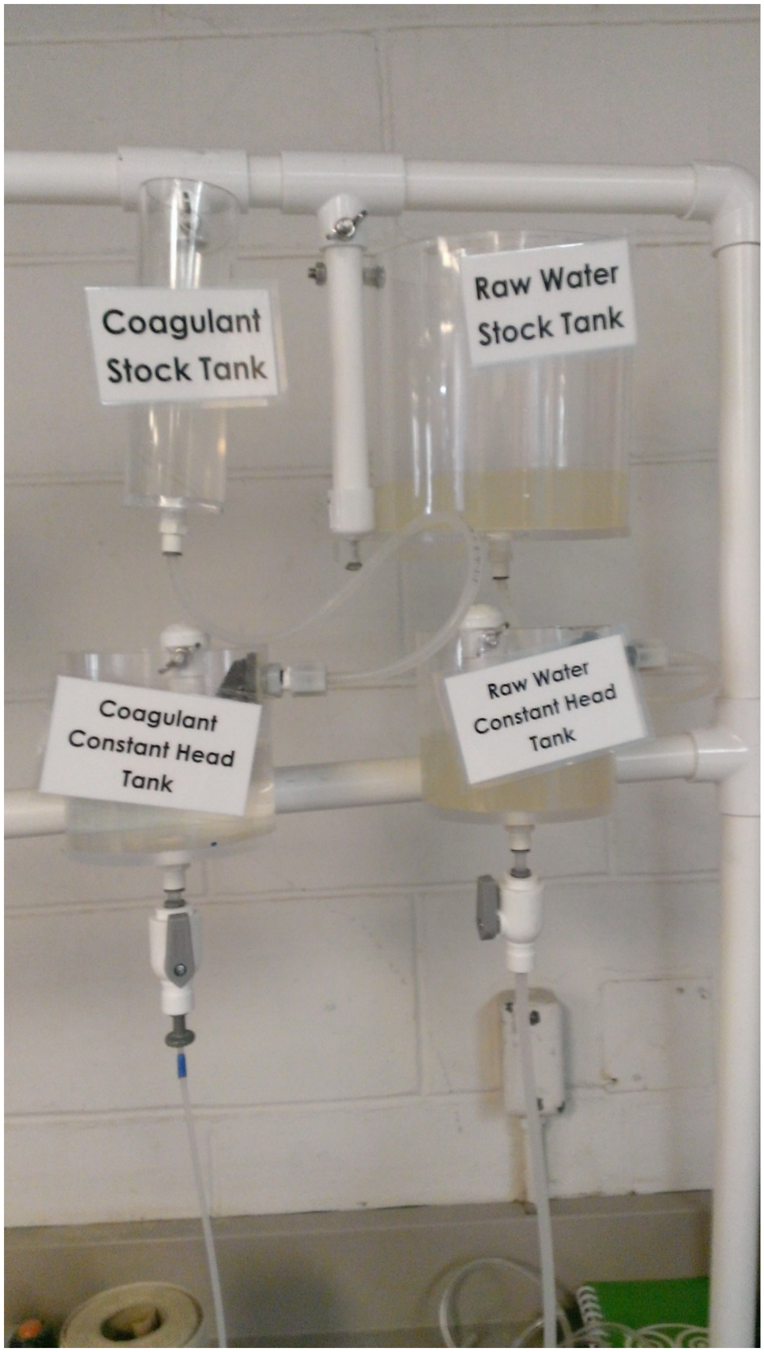

Figure 7: Dosing Tanks

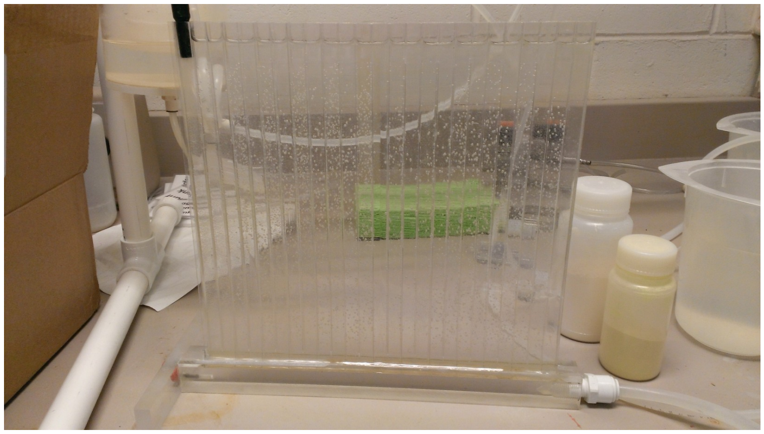

Figure 8: Flocculator

0.5. Chemical Dose Controller

Numerous changes needed to be made to the chemical dose controller: the drop tube needed to be extended to the low water level in the entrance tank, so that there was always coagulant in the tube. This minimum elevation in the entrance tank was measured by finding the head loss in the coiled tube leading from the entrance tank to the flocculator. Counter weights also needed to be added to the dose controller so that the dose varied with the height of the entrance tank, and the doser would move with the water level, rather than being weighed down by the chain or the entrance tube. However, the longer drop tube provided a large increase in weight that was sufficiently offset by adding 4 washers to the float valve's chain. A final adjustment was calibrating the dose controller, measuring, and calculating coagulant dose and concentration in order to label the dose controller with these values.

Analysis:

The new fittings on the SRSF work well, both when running the plant and backwashing the filter. Also, plant assembly is now much easier and faster with the backdrop layout sheet and new users manual, complete with troubleshooting tips. We successfully fixed the flocculator by replacing the broken one. The new foot works well, but could definitely be improved in future flocculator designs. The new chemical dose controller works much better than it did previously; the counterweights improved the lever functionality and dosing consistency. Also, the ideal flow rates have been achieved and are now labeled on the plant. However, there are a lot of improvements to be made and more work that should be done. Most evident is that the flocculator could be designed and manufactured better to make it less fragile – this is key because the demo plant moves around so much and needs to be reliable. It is also increasingly evident that the flocculator is unstable on its own as the plant is running. For example, In Figure 8 you can see that the Flocculator must be carefully oriented to prevent tipping, even with the foot added to one end. One idea to improve stability without compromising size or strength is to add two feet to the bottom of the flocculator, attached with a flat head screw so that they can swivel for transportation while maintaining the balance of the flocculator.

0.5.1. Notes

Tables containing our measured flow rates, plant inventories, and measurements for clay and coagulant dosing are compiled in an Excel document in the group folder for Spring 2013.

Conclusions:

We will use what we have learned so far to envision changes to the demo plant. Since we only have one working plant, and possibly face multiple trips for demonstration, our priority is replicating the plant. We have taken a detailed inventory of the other parts we already have for future plants and we communicated with Paul Charles, as well as Diane, Owen, and Monroe to ensure we know how to fabricate the missing parts. It will prove critical to have access to multiple demo plants, in the event that some are traveling, or one part breaks, and a complete demo plant is needed by a given deadline. We have also worked to gather as much information as possible on the demo plant, and have compiled this information to be available on the AguaClara server and wiki page to provide effective guides for future AguaClara researchers. Lastly, it is worth noting that the Demo Plant is a very temperamental setup. Often small things such as specific tube orientation or bubbles in tubing lead to backups in the system or water overflow through the flocculator. This has been noted and presented along with a simple troubleshooting program that we have included in our updated users manual, available on the wiki page as well as the AguaClara server.

Future Work:

Two main priorities for future demo plant work have emerged: testing sturdier flocculator and tank designs, and fabricating additional complete demo plants. A useful way to approach the flocculator would would be to stress test the flocculators to find what may cause cracks, and how this can be better prevented. This information will be useful in making new flocculators for the additional demo plants. It would also be a good idea to try out a few different methods of improving the stability - another foot on the opposite end of the flocculator, two feet on the bottom, connected with flat head screws to allow for swivel and making sure the piece sits flat, and likely more potential ideas as well. It would also be useful to find a way to clean out the new flocculators; they can be rinsed and drained, but it is difficult to clean the flocculators out when clay and coagulant stick to the sides. Similarly, we found that continued use of the acrylic tanks has left them prone to cracking at the point of connection with the screw or wing nut. New materials should be considered for the tanks - we discussed using Nalgene with Monroe and he seemed very receptive to the idea. Finally, as stated earlier, it is crucial to have multiple complete, functional demo plants. We have provided detailed drawings of plant parts with the hopes that future demo plant teams can use this information, parts available, and additional parts provided in the demo plant excel sheet, to complete the three additional plants. Then, these plants should be tested and troubleshooted as necessary. One additional, small task that would help the plant would be to acquire magnetic stirrers to keep in the entrance tank and/or raw water tanks to prevent the buildup and clogging of clay.