# Challenges Spring 2013

## Challenges for Spring 2013

## Team Organization

| Topic | Type of project | Student Advisor | Location | # students |
|---|---|---|---|---|
| PR | | Michelle | | 6 |
| Design | | Anthony | ACCEL | 8 |
| Ram Pump | Research /Fabrication | | | 3 |
| Floc/Sed Optimization | Research - Lab | | Right bench in AguaClara 1 | 3 |
| Tube Flocculator | Research - Lab | | Left bench in AguaClara 1 | 1-2 |
| Tube Flocculator Data Analysis | Research - Mathcad | | | 1 |
| Sedimentation Tank Hydraulics | Research - Lab | | Left end of right bench in 1st floor lab | 3 |
| Depth vs. Surface Sand Filtration | Research - Lab | | Left end of left bench in 1st floor lab | 3 |
| Arsenic | Research - Lab | | Right end of right bench in 1st floor lab | 3 |
| Calcium Carbonate Scaling | Research - Mathcad | | | 1-3 (2-3 week task) |
| Turbidimeter | Research/Invent | | | 1 (Full) |
| Coagulant Management | Research/Invent | | | 3 |
| Full Scale Floc Breakup | Research/Invent | | Project space | 2 |
| LFSRSF | Invent | | AguaClara 2 | 3 |
| Foam Filtration | Invent | | AguaClara 2 | 3 |
| Demo Plant | Invent | | Project space | 2-3 |
| Chemical Doser | Invent | | | 2-3 |

### Design

The design team challenges are available in a separate google doc. The design team will consist of 4-8 students that will work on these tasks individually or in pairs. Desired (but not necessary) skills: Mathcad, AutoCAD, 4540, fluids, Spanish fluency, and engineering design experience.

### PR

Evaluate whether there are benefits to registering as a club (we concluded a club wasn't beneficial previously.)
Work with Engineering College Corporate relations to identify target corporations and donors. Meet with Abby Westervelt of the College of Engineering Corporate relations to discuss strategy.
Goal is to raise funds to support the R&D effort. Explore connections with Autodesk, CH2M Hill, CDM. Also pursue Gates Foundation and Warren Buffet Foundation.
Create an active web presence using blogs and twitters. Create blogs at least every 2 weeks. Sources for blogs are the team trip to Honduras, news from APP, AguaClara LLC, India, and, of course, the Cornell R&D teams.
Lauren Chambliss of the Atkinson Center may be willing to provide some guidance on fundraising as well.
Work with Joe Rowe of CEE to provide photos and videos for the TV screens in the CEE lobbies.
Write a story for National Instruments about the sedimentation tank hydraulics team and how we used the donated NI camera system to learn why floc blankets didn't form in the AguaClara plants that had flat sections in the bottom of the sedimentation tanks. Explain how we used the camera system to test various geometries.
Arrange for Monroe to give a TED talk. (http://www.ted.com/nominate/speaker)
Create a powerpoint slide that addresses the question of what AguaClara technologies do with pathogens. It is very common to think that the AguaClara focus on turbidity removal is misplaced and that we are ignoring pathogens. To address this misunderstanding we need a slide that shows microphotographs of clay particles and various pathogens (Cryptosporidium, Giardia, pathogenic E. coli, Vibrio cholera, etc.) to make it clear that these pathogens are larger than or similar in size to clay and that the same mechanism for removing clay will work to remove these pathogens.

Become familiar with the main WASH sector organizations and forums and devise means of publicizing AguaClara through those forums. For example: Wash Advocates.

### Research

#### Ram Pump

Consolidate and annotate all the information that's already out there on homemade ram pumps – seems like there's a lot of it. Maybe it would ultimately be helpful to draw on those design guidelines to fill gaps in what the research is able to provide. Put all the info we can find in a concise organized format. Create a comprehensive ram pump design Mathcad sheet that covers all the cases we're likely to run into.

- Increase the pumped head to 4 m by installing a pressure relief valve (see image to the right) (Mcmaster 4703K54). The pressure release valve can be adjusted to produce whatever back pressure is desired.
- Vary the wasting valve cycle time and measure the pumping efficiency. Use the theoretical acceleration time of the drive pipe water to guide the cycle time. Develop a method to adjust the valve cycle time.
- Consider adding a flow rate measurement device. Use a vertical pipe that is 70 cm long and that is filled with the pumped water. Measure the height of water in the pipe using a pressure sensor. Dump the water when the measuring device is full using a solenoid valve controlled with process controller.
- Consider swapping the PVC drive pipe for a galvanized iron pipe to see if the flexibility in the PVC pipe has a significant effect on pumping efficiency.
- Evaluate the possibility of building an inline ram pump where the waste continue directly to the distribution tank. The waste valve is no longer open to the atmosphere. First step is to explore this to see if anyone has tried this before. Check patents.
- Evaluate ram pumps that are on the market to see if any of them would be appropriate for our use. Our goal is to have a simple design that can easily be repaired locally.

## Flocculation/Sedimentation Optimization

The first goal is to be able to reliably produce a floc blanket using PACl. This January in Honduras we learned that flocculation can fail quickly when the coagulant is injected into small diameter tubes as are used in the demonstration plants. The hypothesized mechanism is that the coagulant forms precipitates that begin to clog the tubing and that the small pores that are left result in high rate of deposition of the coagulant. The rapid fouling of the flocculation tube is a significant problem for the current experimental apparatus. and theoretical analysis suggests that the majority of the coagulant ends up on the flocculator walls rather than on the clay. This may have been one of the causes of the difficulty in producing floc blankets.

There are two options for reducing the loss of coagulant to the tubing walls. One is to redesign the reactor system to handle a flow rate that is identical to that used for FReTA. This would require changing the entire apparatus and thus is not a great option. The second option is to add a large diameter reactor (perhaps a 250 mL bottle) where the raw water and coagulant are mixed using a hydraulic jet on the raw water inlet. This contact tank would provide an opportunity for most of the coagulant to adhere to the clay and thus the existing flocculator could still be used. The hydraulic jet for the raw water should be designed to have an orifice that generates approximately 1 m of head loss. The coagulant should be injected with microbore tubing that discharges directly into the jet.

The second goal is to add imaging capabilities to the apparatus so that the floc blanket status can be monitored in real time. Work with Lesly Yu of National Instruments to identify a camera that would be able to detect the height of the floc blanket. She may be able to arrange for an in kind donation for the AguaClara team. It will be necessary to add back lighting that could be a narrow strip of LEDs with a light diffuser to create a more uniform light source.

Work with Matt Hurst to interface the camera with the computer. Monroe would like to create several external functions for Process Controller that would process the images and return summary values. One function will take a picture and return the average concentration in a region of interest, another will return the height of the floc blanket using the picture taken by the previous function.. These functions are also needed by the sed tank hydraulics team. The external functions will use an input file with a LabVIEW data structure. A LabVIEW app that can edit the data structure will be provided. The data structure will include the file path of the images, the region of interest, and a file name of the blank image.

Using the new contact tank, vary the coagulant dose, measure time to build a floc blanket and compare the results with theoretical floc build times based on mass conservation. Once you have developed a method to reliably build a floc blanket and have selected an appropriate coagulant dose for further research, then add floc recycle. Use a coagulant dose that has relatively poor performance so it will be easy to see if floc recycle results in an improvement in performance.

## Tube Flocculator

### Test the floc breakup hypothesis

There are 2 unknowns: the optimal energy dissipation rate at the floc breakup point, and the collision potential between breakup points. The optimal solution is expected to be a function of the coagulant dose and raw water turbidity.

Develop a repeatable method of setting the energy dissipation rate of a floc break up contraction. Maintaining circular geometry through the contraction will be impossible for higher energy dissipation rates. One option would be to locate in the lab or purchase tubing clamps that have parallel surfaces with a variable separation. Use a vernier caliper to accurately set the distance between the parallel surfaces and measure the resulting head loss by placing a pressure sensor across the flocculator. However, before adding the pressure sensor, perform fluids calculations to determine if the pressure sensor will be able to measure the head loss across the floc break up points. Note that a 7 kPa sensor has a maximum range of 70 cm and at best a 1% error.

Measure performance at a single coagulant dose that has relatively poor performance and vary the distance between the floc break up points with the goal of finding the separation distance beyond which no additional improvement is observed. Use a short flocculator of 28 m. Test the control without any floc breakup points. Then add a single break up point in the middle of the flocculator. Then add two more break up points to create a distance between breakup points of L.Floc/4. Then add 4 more break up points to create a distance between break up points of L.Floc/8. Continue this pattern until there is no additional beneficial effect.

Then remove some of the breakup points so that performance is significantly poorer than with the maximum number of break up points. Rerun the experiment and then increase the energy dissipation rate at each break up point in a controlled manner and measure performance as a function of the energy dissipation rate.

Depending on the results it may be useful to experiment with even shorter flocculator residence time.

### Test Tapered Flocculation

Design a test with either 2 or 3 different tube diameters and set it up so that the energy dissipation rates are in the range suggested by conventional design guidelines for tapered flocculation. Design this carefully so that you can have a control with a non tapered design that has the same residence time and the same total head loss. Also compare with a floc break up design that has the same residence time and total head loss. The goal is to obtain enough data to form the basis for a paper.

## Tube Flocculator Data Analysis

### Floc sedimentation velocity vs coagulant dose

Process the data from Karen Swetland's research to extract the average floc sedimentation velocity as a function of coagulant dosage. It should be possible to assess which coagulant, PACl or alum, produces flocs with a higher sedimentation velocity given the same aluminum concentration. This task does not require any additional laboratory work. It will require writing code to streamline the data extraction process. Think carefully about the best way to measure the time at which the turbidity is at 50% of the flocculated water turbidity. Some data smoothing or line fitting may be needed to get a reasonable estimate of the time.

Create graphs of mean floc size as a function of coagulant dose for each of the turbidities that are available. Determine if the ratio of mass of coagulant per mass of clay is a good predictor of floc sedimentation velocity. Analyze the results using the insights from our new flocculation model that emphasizes the role of fractional surface coverage. Determine if equilibrium floc size can be predicted from the fractional surface coverage or if a more complex analysis is required. Make sure to take into account that for low turbidity samples more of the coagulant ends up on the flocculator walls.

## Sedimentation Tank Hydraulics

Improve the youtube documentation and provide better descriptions with more detail of the experimental setup. Include coagulant dose, raw water turbidity, presence or absence of plate settlers, and the ratio of the real time to the time of the videos.

The big goals are to provide design and operator guidance for optimal performance of floc blankets to enhance particle capture, reduce the required coagulant dosage, and reduce the fraction of water that must be wasted to remove the sludge from the sedimentation tanks. We would like a design that is easy for the operator to manage and to observe the status of both the floc blanket and the floc hopper.

The flocculator for this apparatus has too low of a collision potential. The collision potential could be increased by doubling the length of the flocculator. This should make it easier to operate the floc blanket at lower turbidities.

Parameters that we would like to define include:

- Optimal upflow velocity in the sedimentation tank (currently set at 1 mm/s)
- Optimal ratio between floc blanket area and floc hopper area. Increasing the area dedicated to the floc hopper will decrease the wasteage of water and will increase the capital cost.
- Influence of depth of floc hopper on consolidation of the sludge. Perhaps the depth of the flocculator is primarily beneficial because it increases the interval between draining the floc hopper.
- What are the tradeoffs between continual wasteage and intermittent wasteage? Continual wasteage that keeps the floc hopper full would likely result in a lower average flow rate of waste. However, it might be more difficult to operate unless the operator can observe the floc hopper depth and regulate the flow easily.

Given a volume below the floc weir and an influent turbidity, develop a relationship that roughly gives the time until full floc blanket formation. This would be a useful guide in the field.

### Experimental steps.

1. Lengthen the flocculator
2. Switch to using PACl
3. Conduct a series of experiments at 100 NTU varying PACl dose and measuring the resulting effluent turbidity from the tube settlers and the floc blanket concentration. Compare your results with the data from Matt Hurst using alum. Ideally compare this on a mole of aluminum basis
4. Implement external functions in Process Controller to measure height of sediment in floc hopper (see floc sed optimization for information on proposed external functions).
5. Use measured height of sediment to control the peristaltic pump that removes sludge from floc hopper. PID or simple on/off control could be used to control the sludge pump. This will make it possible to measure the flow rate and indirectly the concentration of the resulting sludge and hence to conduct experiments on the effect of floc hopper plan view area and depth.

## Depth vs Surface Sand Filtration

The big goal of this research is to understand the difference between surface and depth filtration and the parameters that determine which regime is operative. We suspect that subsurface injection of the water to be filtered shifts the regime to depth filtration. Begin by conducting a literature search to find discussions of depth and surface filtration.

Depth filtration likely occurs when the fluid forces on the flocs that bridge across a pore in the filter bed exceed the strength of the flocs. Thus the dimensionless parameter that determines whether depth or surface filtration occurs must include both floc strength and pressure drop through a thin layer of flocs. Pressure drop through a thin layer of flocs is influenced by the porosity of the flocs which is a function of their fractal dimension. Small flocs are less porous than large flocs and thus small flocs are less likely to produce surface filtration.

The laboratory research goals of this research are to determine the difference in head loss and particle capture efficiency between conventional rapid sand filtration where raw water is added above the filter bed and SRSF where the water is injected into the filter bed through slotted pipes.

Set up two filters in parallel that both receive the same raw water but with one filter operating as a conventional rapid sand filter and the other filter having the raw water injected below the surface of the sand.

## Arsenic

Devise methods to conduct research safely and to ensure safe disposal of arsenic contaminated waste. Determine the best way to prepare and to measure very low concentrations of arsenic. Design a reactor system and data collection system that will make it possible for us to begin to optimize treatment processes for efficient and reliable arsenic removal. Determine how to create a raw water for testing. Should the raw water be created from distilled water or from tap water? What should be added to the raw water to set the ionic composition? How should pH be controlled?

The processes of flocculation, floc blanket, plate settler sedimentation, and filtration are expected to remove As (V). The removal of arsenic by precipitation is expected to be limited by the transport of arsenic to the solid surface of the coagulating agent (either iron or aluminum salts). The flocculation process for groundwater containing arsenic is expected to be inefficient due to the low floc volume fraction. To compensate for the low floc volume fraction it may be necessary to use a longer residence time. Loss of coagulant to the walls of the reactor will also likely be a major problem for small scale reactors given the low solid surface area in suspension. It may be advantageous to use a contact chamber for rapid mix and initial precipitation to reduce losses to the reactor walls.

If this is the case, then a floc blanket consisting of precipitated coagulant could be an efficient reactor for arsenic removal.

### Big questions to begin answering

- Which coagulant, Fe(Cl)3, alum, or PACl is better at removing arsenic?
- Is arsenic removal limited by the mass transfer of arsenic to a precipitated coagulant surface, or by capture of the precipitated coagulant by plate settlers and filters?
- Would a floc blanket formed from coagulant precipitate enhance arsenic removal?
- Does addition of a small amount of clay enhance flocculation and arsenic removal?
- How can we reduce the amount of coagulant loss to the reactor walls? (contact chamber, clay)
- What is arsenic removal correlated with?

## Calcium carbonate scaling at Las Vegas, Honduras

Several students who took 6530 can analyze how much acid must be added to the Las Vegas water to move it away from supersaturation and to prevent precipitation in the distribution system. This task will be a one or two week task. The chemical analysis should be done using Mathcad.

The composition of the groundwater should be assumed to be rainwater that is in equilibrium with calcium carbonate at a given input temperature. Thus the initial pH of the groundwater should be a calculated value. The temperature of the water in the distribution system is another important input. The system of equations should calculate the amount of acid that must be added to keep the water from precipitating. The required dose of aluminum sulfate should also be calculated. It may be possible to create a simple algebraic equation to solve this problem. Explore the options for creating a simple equation because simple equations provide insight into what is controlling the process.

## Turbidimeter

Design a low cost turbidimeter that can be used by plant operators and that will simplify data reporting. Alex will work on this solo.

## Coagulant Management

Coagulants are a significant operating cost and thus it is important to use them efficiently. Coagulant management includes stock preparation, testing stock concentrations, dosing with the chemical dose controller, and injection of the coagulant into the raw water. As part of the AguaClara design philosophy these steps need to be done efficiently and we need to provide appropriate feedback to the operators so that they know when they have done these task well.

We need a method to measure the concentration of coagulant in the chemical stock tanks. A hydrometer could be used if we can develop the relationships between density and coagulant concentration. Ideally we can obtain hydrometers and change the labels so that the read out is coagulant concentration.

Analyze chemical mixing methods. We previously explored using a simple hand operated centrifugal pump inside the stock tank to mix high density stock solution with the overlying low density water. We need to do the theoretical analysis of this system to see if it is practical at full scale and if it is, then we need to devise fabrication methods for this mixing system. If the centrifugal pump system isn't feasible, then we need another mixing system that can be installed in the stock chemical tanks.

## Full Scale Floc Breakup

We have two indications that small flocs are needed to aggregate with colloids. The flocculation model based on the physics of the aggregation process only fits the data if we assume that large flocs are no longer reactive. A preliminary experiment using the tube flocculator and FReTA shows a significant reduction in settled water turbidity when the flocculator had 6 floc breakup flow constrictions. Although all of our experimental work is based on laminar flow tube flocculators, the results are quite similar to full scale hydraulic flocculator performance and the flocculation model explains the need for the 1000 second retention time. Thus we should begin to explore the implications of our new understanding of the flocculation process on full scale hydraulic flocculators.

The flocculation model predicts that flocculator performance would be substantially improved if the large flocs were routinely broken so that they could collide and attach to colloids. The goal of Full Scale Floc Breakup is to design a device that can be added to a hydraulic flocculator in Honduras to test the hypothesis that floc break up improves the performance of full scale hydraulic flocculators.

The floc breakup device must have the following characteristics:

- Head loss through the device must be minimal. Head loss is directly related to the fraction of the flow area that is blocked by the device. Thus the device will need to have a large fraction of open area.
- The device will need to create a high energy dissipation rate. One possible rational basis for this energy dissipation rate is that the flocs leaving the floc break up device should have a terminal velocity that can be captured by the plate settlers.
- Minimize head loss and yet create a high energy dissipation rate can be accomplished by creating very tiny jets. Thus the floc break up device will likely be made using a wire mesh. If the mesh size is too fine it will clog easily. The challenge here is to design a mesh size that doesn't clog and that minimizes head loss.

The goal is to design a device, invent fabrication methods for installing the floc breakup device in a plant in Honduras, and work with the team at APP to test the performance of the device. Drew Hart will be testing floc blanket performance at Atima in the coming months and thus this test could be added to his research program.

# Invent

## Low Flow Stacked Rapid Sand Filter

Rebuild and create a 3rd generation LFSRSF with a focus on simplifying fabrication and operation. This project will require a mixture of fabrication innovation, hydraulic analysis and design, and creativity. Fairly extensive documentation on stacked rapid sand filtration principles can be found on the wiki. It would be advisable to become familiar with the research done in previous semesters as well as the research paper published by Mickey and Monroe. There is also a dedicated document on the construction of the low flow filter on the wiki. This document should provide some insight as to the construction techniques used to create the first and second generation filters and the design decisions.

- Improve slotted pipe manifold design. During testing in honduras, the slotted pipe manifolds were cracked and allowed sand to leak out of the filter outlet. This caused a premature end to the testing process. While the cause of the failure was not something the fIlter was designed to withstand (it got dropped off the truck), the manifold design is weak and needs to be improved. Currently holes are drilled in the 1" trunk line and the half inch slotted pipes are then glued into the holes. This means that there is very little surface area holding the slotted pipes in place. I might be possible to use reducing crosses to hold the pipe stubs in place but they may have to be modified to avoid covering up too many slots.

- Improve pipe drilling methods both for filter body And for slotted pipe manifolds. See the construction documentation for a more complete idea on how the body was made.The shop that made the body in Honduras used a knife type arrangement to cut the pipe on a drill press (email Drew Hart for more details), the Machine shop in Ithaca used a forstner bit. Are there other options and is it possible to replicate the Honduras method?

- Improve the cap design. In Honduras, During backwash the aluminum caps appeared to suck in air around the threaded fittings which had detrimental effects on backwash performance. Remake the caps and see if the failure can be recreated using compressed air and snoop (soapy water test for creating bubbles). The pressure should be equivalent to the negative pressure experienced during backwash (this can be calculated from the backwash analysis mathcad sheet which should be on the wiki). Also look to improve the gasket design so that it seals against the pipe end better and is easier to tighten (consider using locktite on the studs that hold the access cap in place).

Also consider different cap designs that might reduce costs. The current design requires roughly $200 in aluminum and there may be a less resource intensive way of construction. Also tweak the access cap design so that the heads of the bolts do not interfere with the seal of the cap.

- Design a sand drain system at the bottom of the filter to enable the sand to be easily removed from the system. Implement this on the lab filter.

- Rebuild the filter in the lab (this will require ordering more slotted pipe and flexible couplings, making new caps and manifolds and reconnecting to the hydraulic test facility. Once constructed, attempt to establish what the head losses are at clean bed and during backwash, also establish what terminal head loss during filtration should be. It would also be a good idea to rebuild the inlet manifold to reflect the current design in Honduras as well as the backwash system.

- Create an operator's handbook that will enable a user to set up an already constructed filter, run the system in filtration and backwash, troubleshoot the system, and make basic repairs. Translate to Spanish.

- Make recommendations on ways to expand the filter line. Investigate the possibility of using corrugated larger diameter pipe to make a 2, 4, or 6 l /s filter. Investigate the possibility of using two 55 gal drums welded together to make a large diameter body. Consider the ways the slotted pipe manifolds could be attached through the pipe walls. Do the hydraulic design for the slotted pipe manifolds for the higher flow filter.

- Redo hydraulic analysis during backwash to figure out why the valve is necessary on the filter outlet. The design is such this valve should not be needed.

- Design a stand alone system for treating water with less than 10 NTU. Investigate the possibility of creating an automatic shut off system if coagulant or chlorine runs out, and an automatic backwash system. The backwash system could be actuated using a valve that is opened when the water level reaches terminal headloss in the inlet pipe. Some sort of timing mechanism will be needed to turn backwash off after a predetermined amount of time and reset the system for the next backwash (email Harrison Gill for thoughts on the system).

## Foam Filtration

The big goal is to design a filtration system that is ready to deploy in a small community or for a school or similar institutional setting. This will require attention to the details of fabrication, creating a simple design that can be easily replicated, and sourcing materials. Create a well designed and easy to use system. Eliminate use of 8020. Add the dosing system for coagulant and for chlorine as integral to the apparatus and not as an add on. The foam filtration system should be designed so that given a water source with some method of regulating flow rate, that the flow can be measured and easily regulated. The chemical dosing systems should use an AguaClara dose controller. It may be advantageous to use a shorter lever or to reduce the head loss through the LFOM and dosing tubes to 10 cm.  The PVC pipes should be make of standard white PVC. Develop methods for the operator to easily track head loss in each of the filters.

The final foam filter should be easy to assemble, look professional, be easy to use, and provide excellent operator feedback.

In applications where the filter foam will come into contact with a liquid-based solution, the filter foam should be manufactured with polyether-based polyols. In applications where the filter foam will come into contact with gases, such as oxygen, nitrogen and/or carbon dioxide, the filter foam should be manufactured with polyester-based polyols. (http://www.newenglandfoam.com/filter.html) Verify that the reticulated foam in the lab is polyether-based polyols. If the foam we have is incorrect, then obtain the correct foam prior to further research. Research

Previous teams have hypothesized that the foam wears out. Develop a method to conduct long term trials of the foam filter system. This could either be in the lab or in Honduras.

## Demo Plant

The new demo plant is a great improvement over our previous design. It now needs to go through a few iterations of testing and fixing design errors and making it easier to use.  We need a demo plant by Feb. 14 that is ready for presentations in India.

- Correct elevation errors** Coagulant constant head tank is higher than the discharge elevation of the coagulant into the drop tube
  - Drop tube long enough so that the bottom of the drop tube is always full of coagulant
  - Determine the correct tubing lengths for flow control of water and coagulant and appropriate head loss from entrance tank to flocculator
- Zero doser (zero flow through plant lever is horizontal)
- Add counterweight to lever so that dose can be adjusted without the lever falling on the float side
- Calibrate doser (put a percent scale on the lever as we are proposing for the new doser) and label the maximum dose.
- Label chem stock tank with concentration of coagulant
- Add stabilizing feet to flocculator
- better method for mixing up coagulant and clay (single scoop per liter of water)
- O-rings on seal system for top of sed tank wear quickly. Design a better system.
- Develop protocol for setting up and backwashing filter that methodically remove air from the tubing and filter.

## Chemical Doser

The chemical doser is one of the key AguaClara technologies and it is critical for successful plant operation. The

1. Build another prototype possibly working with Hancock Precision who anodized and engraved it. They said they could build the whole thing for us but it would be rather expensive. Alternately work with the CEE shop to fabricate a new unit.
2. Figure out a good way to do the constant head tank for larger flow rates. It requires a bigger float/float valve.
3. Better Float. Some of the floats in Honduras move around excessively because of a lack of a heavy enough counterweight and because of poor entrance tank design. Explore options for better floats including buoys and floats that are shallow (more like a cake pan).
4. Anodizing didn't work great, because it was turning purple. Either figure out why it changed color so it can be prevented or paint it. Assess the durability of the anodized surface in a wet environment.
5. Develop a better method to zero the constant head tank - minor height adjustments to the lever or constant head tank were difficult and cumbersome.
6. The lever arm is big and might not fit in all the plants (This may be fixed by the better entrance tank geometry in the future)
7. Figure out if we can build the dosing tubes directly to specifications and expect them to work. This would minimize calibration time. The main concern is the dosing tube length
8. Create a better manifold system that is chemical resistant.
9. Document how all of this is to be done in clear concise product data sheets. Right now this knowledge is in David, Andrea, Rudy, Tim and Paul's heads' not written down anywhere. This could include documentation for fabrication and calibration.
10. Figure out retrofits for existing plants.
11. Determine how the doser systems should be fabricated in the future. Should they be produced and then sold by AguaClara LLC or should they be produced locally in each country?
12. Further performance testing.

## Small Scale Plant Model

Understanding the layout and processes of AguaClara plants can be difficult if one has never seen a plant.  This team will design and create a small scale plant that can be used to demonstrate how the plant is laid out, where each process takes place and how it can be taken apart for cleaning.  Potential donors and partners, in particular, will benefit from the small scale plant as they will be able to more easily understand the plants.

- Design and construct a small scale plan that can be used to present the AguaClara design.
- The final product should look like a model from the design tool.
- Include labels and features to distinguish between different processes in the plant.
- Be able to take up square footage of a laptop and be easily portable.
- Can be taken apart in the same way as a full scale plant.