# Milli-Sedimentation, Fall 2016

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**Abstract**

The goal of the milli-sedimentation team was to find and explore the boundaries between sedimentation and filtration which could be used to reduce the size and residence time of AguaClara plants . The technology was designed using coffee straws that are sized between the spacing of plate settlers ( 10mm) and the porosity of filter material ( 0.1 mm). The size of the plant would be on the scale of a a small town or village, less than 1000 residents, replacing what the foam filter did in El Carpintero . One of the biggest challenges for the semester after building the sedimentation-filtration system was attempting to clean the apparatus, as this determined the feasibility of the design.

## Introduction

The Milli-Sedimentation team explored whether an apparatus with straws of short diameter ( 1mm), i.e. coffee straws, could increase the efficiency of sedimentation and filtration by combining the two processes. The milli-sedimentation tank was designed using ordinary coffee straws arranged in a honeycomb similar to the design of conventional tube settlers. The straws served as a porous media that replace the sand pores created in sand filters. Flocs were expected to settle onto the straw surface as they would in any sedimentation system but in addition, particles could be removed by attaching to the inside of the straws as they would in filters. The purpose of the short diameter of the straws was to reduce the size of the sedimentation tank.

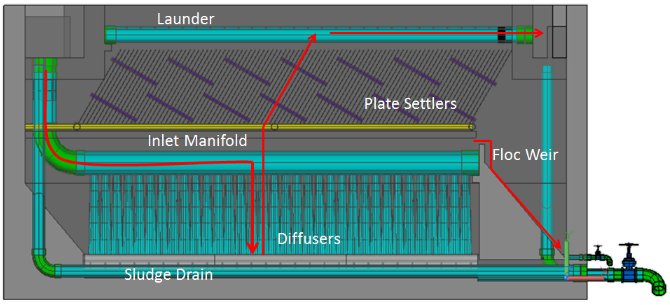


Figure 1: In traditional AguaClara plants, plate settlers are used for sedimentation. The flocs settle down the plate settlers and flow out through the sludge drain. The clean water flows out of the top. An advantage of this system is that it is self-cleaning.

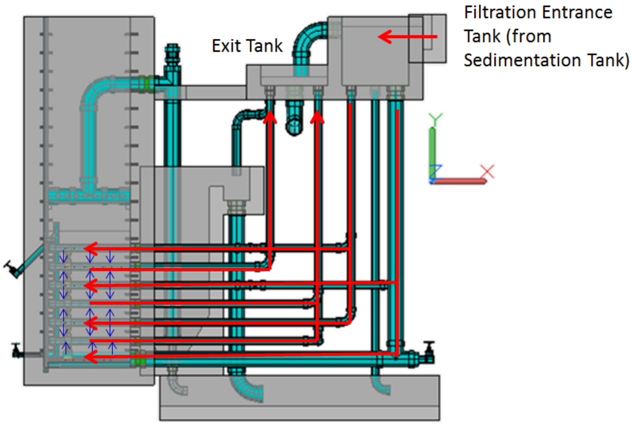


Figure 2: AguaClara filters use multiple layers of sand to filter out small particles.

This design is advantageous to conventional sedimentation, figure 1, and filtration, figure 2, because it is smaller and therefore easier to build and more portable after construction. The goal of implementing this apparatus would be to reduce the size of AguaClara plants while maintaining their ability to provide clean drinking water. Combining the processes of filtration and sedimentation would decrease the cost of an AguaClara plant.

## Literature Review

Sedimentation is the process of removing particles from water after flocculation using gravity. For a horizontal flow sedimentation tank, shown in figure 3, the distance the floc travels before settling to the straw surface is determined by the flow rate and the diameter of the straws as shown in figure 4. Conventional horizontal flow tanks have a settle capture velocity, Vc, or the velocity that particles settle to the bottom of the tank, between 0.24 and 0.72 $mm/s$. AguaClara uses a velocity of 0.12 mm/s as a capture velocity for plate settlers to reduce effluent turbidity as much as possible.(Weber-Shirk, 2016)

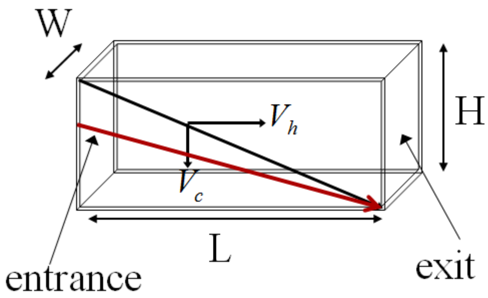


Figure 3: In a basic horizontal sedimentation tank, flocs settle to the bottom of the tank as the water travels horizontally through the tank, and clean water leaves on the right. $Vc$ is the capture velocity and $Vh$ is the horizontal component of the velocity. In this scenario $\alpha$ is zero.

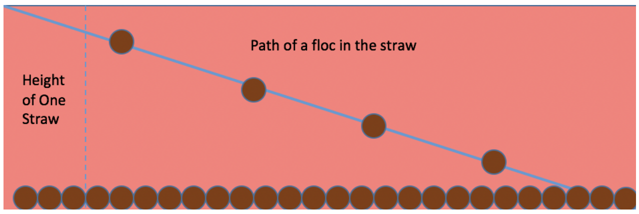


Figure 4: Each individual straw acts as a sedimentation tank. The diameter of the straw is the height that a floc has to fall to be settled out. Some flocs attach to the sides of the straws along the path as well.

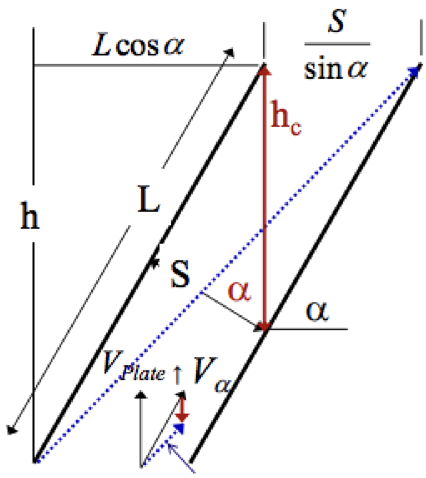


Figure 5: Vertical sedimentation is what is currently used in AguaClara plants. $\alpha$ is the angle of the plate settler. In horizontal sedimentation, $\alpha$ is equal to zero.

The 0.12 mm/s capture velocity is used to result in the lowest effluent turbidity. To calculate capture velocity for a specific sedimentation tank, Equation (1) and Equation (2) below are used.(Weber-Shirk, 2016) $\alpha$ is the angle between the horizontal and the plate settler, shown in figure 5, in the case of a horizontal tank, it is zero. $V\uparrow$ is the upward velocity through the plate settlers. L is the length of the sedimentation tank, and S is the height of the sedimentation tank. In the case of milli-sedimentation, S is the diameter of the tube. $V\alpha$ is the velocity in the direction of $\alpha$ which in a horizontal tank is the horizontal flow rate.

$$\frac{V\uparrow}{V_c} = \frac{L}{S} cos\alpha sin\alpha + sin^2\alpha \tag{1}$$

$$\frac{V\uparrow}{V_\alpha} = sin\alpha \tag{2}$$

Using substitutions from Equation (1) and Equation (2), Equation (3) was derived. Alpha represents the angle from the horizontal to the plate settlers.

$$\frac{V_\alpha}{V_c} = \frac{L}{S} cos\alpha + sin\alpha \tag{3}$$

Once Vc is determined, and based on the controlled flow rate,the specifications of the sedimentation tank can be calculated using equation (4).

$$V_c = \frac{Height * FlowRate}{Volume} \tag{4}$$

## Previous Work

AguaClara has previously done work in replacing the sand filter or sedimentation tank with the foam filter. The Fall 2015 backwash team worked on cleaning the foam filter while the Fall 2015 Foam Filter Preflocculation team worked on optimizing performance. The Foam Filter Team concluded that using the smallest size of foam produces the cleanest effluent water; however using the smallest size would not allow for proper backwashing (Yin et al., 2015) (Whiting et al., 2015). Therefore research in this area was halted as the team realized that in order to achieve the same cleaning efficiency as sand filters, an impossibly small porosity would be necessary.

The StaRS Filter Theory team has been developing mathematical models to describe sand filtration. Their first model of a filter was capillary tubes which helped the Milli-Sed Team develop an idea that straws can act similar as the capillary tube, shown in figure 6. However, this model was proven incorrect because the estimated floc size is too large and the the flocs fill up the volume faster than the model projects. The team has concluded that it is the constrictions that create filtration(Chu et al., 2016).

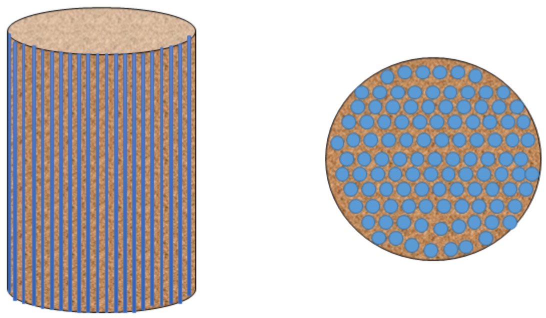

Figure 6: Capillary tubes used as a model for filtration in the StaRS filter. On the left is the view of the filter from the side, on the right is the view of the filter form the top.(Chu et al., 2016)

# Methods

Flocculated water was pumped through a Milli-sed tank to see how flocs behave in a Milli-sed tank. A lab scale Milli-sed tank was constructed by filling a PVC pipe with straws that act as tube settlers. The tank was designed using the capture velocity of clay because if a Milli-Sed tank can remove clay, it can remove the same amount of flocs due to a larger mass.

## Sedimentation tank capacity analysis

The maximum capacity of flocs, or how many flocs can fit fully in a sedimentation tank is a critical value for determining how long we can run the test. According to the 7.5 inch sedimentation tank design and the latest 72 hour test from November 8th to 11th, the average influent clay turbidity is 20 NTU. The diameter of a floc is estimated to be about 1000 micrometers. Based on the floc density as a function of size equation, The density of a floc is calculated about $1.028\frac{kg}{L}$. The team also calculated the total volume of 54 straws in the sedimentation tank to be 0.013 Liters and the total volume of sedimentation tank to be

0.097 Liters. Thus, the full volume of water that can fill the sedimentation tank is about 0.084 Liters.

By conservation of mass, 6, the total mass of a floc(volume of floc times density of floc) is equal to the sum of the mass of water and clay. The total volume of a floc is equal to the sum of the volume of water and clay, 7. Deriving those two equations, the ratio of volume of floc per volume of water in a sedimentation tank is calculated using the following equation 5:

$$\frac{V_{floc}}{V_{water}} = \frac{C_{clay}}{\rho_{clay}} * \frac{\rho_{clay} - \rho_{water}}{\rho_{floc} - \rho_{water}} \tag{5}$$

This volume ratio is around 0.0003065. The team determined that the sedimentation tank can treat 110 Liters water to reach the maximum capacity of floc in it. It also would theoretically take a 5.27-day continuing test based on the $0.25\frac{mL}{s}$ flow rate. So, in a sense, the theoretical operating time can be compared with experimental time to analyze the performance of Milli-sedimentation tank.

$$M_{floc} = M_{water} + M_{clay} \tag{6}$$

$$V_{floc} = V_{water} + V_{clay} \tag{7}$$

## Experimental Apparatus

All experiments pumped clay, coagulant, and water into a flocculator followed by a Milli-sedimentation tank. Turbidity was measured before and after the Milli-sed tank to measure Milli-sed floc removal performance. The apparatus can run in two functional ways, forward testing and backwash. Throughout the testing process the sedimentation tank design was changed to increase sedimentation and filtration efficiency. The design of the system can be seen below in a Figure 7 and Figure 8.

**Schematic**

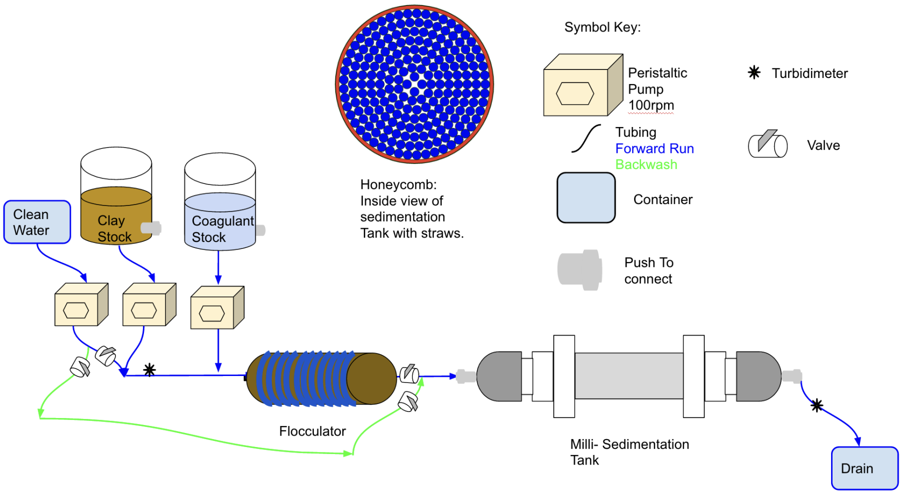


Figure 7: This Milli-Sedimentation experimental system was used for all experiments except the Milli-sed tank was replaced. The influent water is a mixture of clay, coagulant, and tap water that are pumped in. It then flows into a turbidimeter then through a flocculator then the milli-sedimentation tank, into another turbidimeter and then out through a drain.

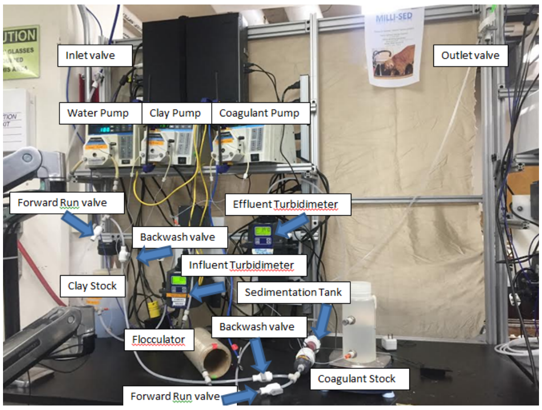


Figure 8: This a labeled photograph of the milli-sed experimental apparatus from the lab.

**Flocculator and Sedimentation Design**

The influent water mixture and flocculator design were based on the StaRS filter theory team's apparatus design. This is a suitable design because the StaRS team is doing filtration without sedimentation and the filter dimensions used in the deisgn of the milli-sed tank were from their design. This made it possible for the team to compare their data from sedimentation with the filter data from the

StaRS team. The flow rate of the overall apparatus was 0.5 $\frac{mL}{s}$. The influent turbidity was 5 $NTU$ of clay. The team added humic acid at a concentration of $1\frac{mg}{L}$. The StaRS team found that the best coagulant dose for this clay dosage is $0.7\frac{mg}{L}$ (Chu et al., 2016). The diameter of the flocculator tubing was $\frac{1}{8}in$ and the radius of curvature of the cardboard tube the team wrapped the flocculator around was $3.5in$. The length of the flocculator was calculated as $9.864meters$ and the energy dissipation rate was calculated as $16.395\frac{mW}{kg}$.

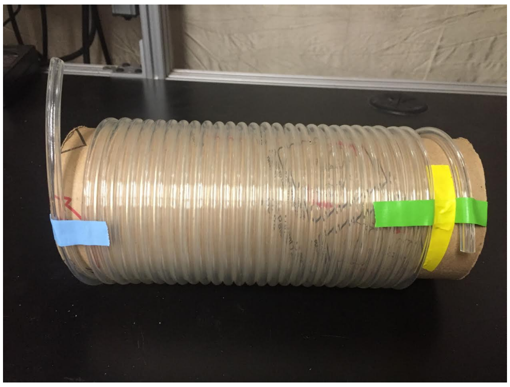

Figure 9: The constructed flocculator was 9.8 meters in length when the tube is unraveled. This generates flocs that will settle out in the sedimentation tank that immediately follows the flocculator.

Using Equation (3), the ratio of $V\alpha/Vc$ can be calculated using the spacing of particles for L (length) and S (spacing). The length of the a sand filter is 200 $mm$ and the spacing between sand particles was 0.2 mm. From these constraints, $V\alpha/Vc$ is 1000 , but since this ratio would be very difficult to achieve in the lab we reduced it by a factor of 10 to 100. From this the team took $V\alpha$ to be equal to $1\frac{mm}{s}$ .To design the sedimentation tank, the team calculated the capture velocity, $Vc$ ,as the velocity to capture clay particles. The capture velocity is calculated using the following equation (8):

$$V_{C_{clay}} = g * \frac{(d_{clay})^2}{18\nu} * \frac{\rho_{clay} - \rho_{water}}{\rho_{water}} \tag{8}$$

The length of the sedimentation tank was calculated as 8.2 *inches* using the following formula (9):

$$L_{tube} = \frac{V\alpha}{Vc} * D_{tube} \tag{9}$$

Coffee straws were not available in this length, so the team ordered 7.5 *inch* straws. Therefore the sedimentation tank was 7.5 *inches* in length. The team fit 54 straws in this tank. Straws are stacked in a honeycomb fashion shown in 7. After initial testing, the team decided to construct a second sedimentation tank that was double the length of the first tank. This tank was $15inches$ long but has the same density of straws. Therefore there were 108 straws in the second tank.

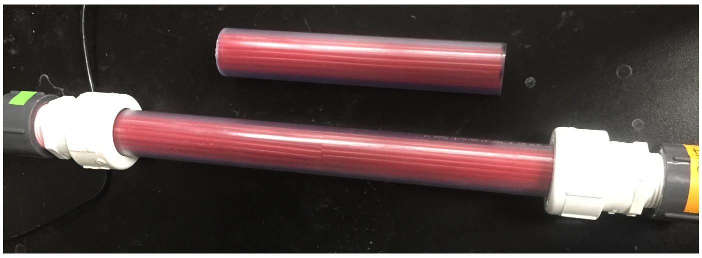

Figure 10: The 7.5 inch long sedimentation tank is shown above the 15 inch long sedimentation tank. Both are 1 in in diameter. There are 54 straws per 7.5 inches in each tank.

#### Complications in construction

There were many challenges in acquiring straws for the apparatus. Drinking straws could not be found with a 1mm diameter, and small diameter coffee straws are opaque and colored. Therefore the team used 3mm red straws to start with and then ordered 5.6 mm diameter clear straws to be able to see inside the apparatus during testing.

#### Procedure

The standard operation procedure for the experiments and ProCoDA method files can be found in the appendix at the end of the report.

## Results and Analysis

### Initial Testing of apparatus feasibility

Initial tests were performed to determine whether the team's initial tank design could remove particles from water and at what efficiency it would run. The tests were repeated three times to ensure the replication ability of the the data.

#### Clogging of Milli-sedimentation tank over time

Floc build up results in headloss that is a measure of the pressure difference across the milli-sedimentation tank, shown in Figure 11.

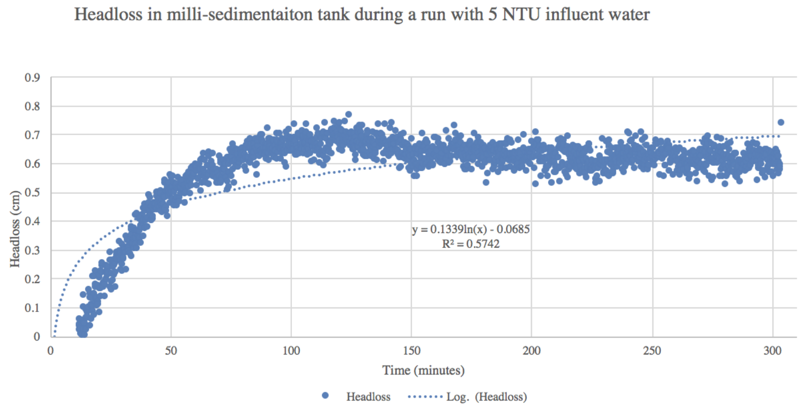


Figure 11: Headloss measured across the milli-sedimentaton tank during the first 150 minutes of the 4 hour forward run. The tank is 7.5 inches long and has a straw diameter of 3mm. The increasing headloss shows the priming of the filter as the first flocs begin to stick inside.

Headloss was measured during a 4 hour forward run. The initial increase in headloss, during the first 100 minutes, was when the straws had not been primed, meaning that there were no flocs attached to the straws. Thus, there was plenty of surface area for flocs to attach or settle. There is steady headloss over time. This suggests that after the first 100 minutes the tank hits its maximum capacity of flocs and then floc-build up stops. From this graph, the team would predict that after 100 minutes, the pC* would drop to zero meaning that for all the flocs that enter the same amount leave. The pC* graph 12 does not agree with this prediction.

### The plot below measures Floc Removal Efficiency over Time

For all testing of the removal efficiency of the apparatus, pC*, Equation 10, is used as a model.

$$pC* = \frac{EffluentTurbidity}{InfluentTurbidity} \tag{10}$$

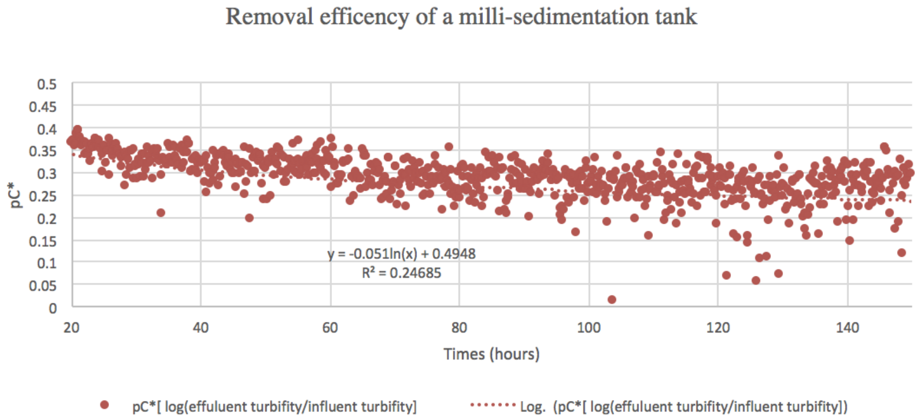


Figure 12: Performance measured across the milli-sedimentation during the first 150 minutes of a 4 hour forward test. The test shows the pC* was close to steady over time. The initial build up was due to the residence time that it takes for the influent NTU to reach the sedimentation tank. The performance was very steady although it slightly decreased over time.

The increase in headloss indicated that the apparatus was filtering, which was part of its goal. When the headloss levels off, this could have indicated that filter breakthrough occurred. These results were expected. However, pC* became less consistent as time increased. Comparing the headloss and pC* graphs indicated that there was a correlation between headloss stabilizing and pC* losing consistency. AguaClara's standard for pC* of a filter is 1. The apparatus currently does not meet that threshold but that can be improved with repeated tests and design modification. Design modifications could involve increased the length of the sedimentation apparatus to increase residence time. A key indication that the apparatus was making progress to design goals was the presence of flocs in the apparatus. When the device was opened to check, the water inside of it contained visible flocs.

**The plot below measures Floc Removal Efficiency over Time**

The team then doubled the length of the sedimentation tank from 7.5 inches to 15 inches. The team also discovered that the sedimentation tank was not completely full of water, so the team held the sedimentation tank vertically while water was pumped in so that air could escape through one side of the tank. The new removal efficiency of the full tank is shown in graphs 13 and 14.

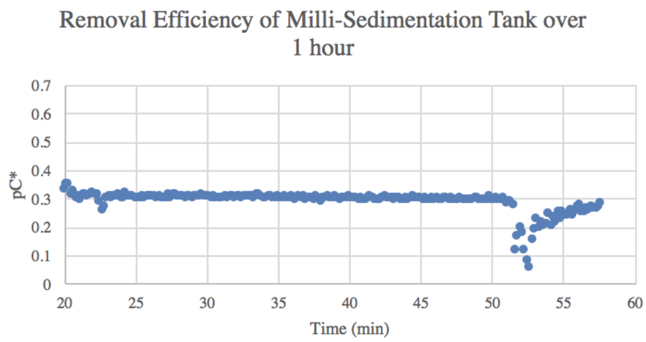


Figure 13: Performance measured across the longer milli-sedimentation tank across 1 hour. Breakthrough is shown to occur at approximately an hour, when the headloss rapidly decreases as flocs are pushed out of the tank.

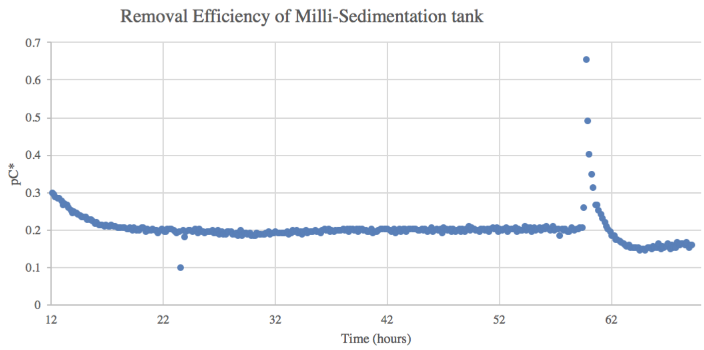


Figure 14: Performance measured across the milli-sedimentation tank during the first 150 minutes of a 4 hour forward test. Breakthrough is shown to occur at around the first hour of the test, which is consistent with the previous graph.

This test showed a consistency in the pC* or removal efficiency of the milli-sedimentation tank when the length was doubled. The pC* did not increase like the team expected. This could be due to the fact that the initial 7.5 in tanks were long enough for complete sedimentation to occur, so any extra length beyond 7.5 in did not contribute to sedimentation. The data was significantly more consistent than a shorter tank. Breakthrough is clear in these experiments occurring after about 1 hour in both tests. Through observations during these test, air bubbles were discovered in the disconnect between the two straws that made up the 15 inches. These air bubbles could block the entrance of flocs or water to whole tubes in the apparatus that then are not contributing to sedimentation. Therefore the team decided to go back to the shorter tank because the air bubbles were not present and therefore did not impact the results.

**Headloss and Removal Efficiency measured over 72 hours.**

The goal of this test was to determine how long the milli-sedimentation apparatus could efficiently remove particles. The team used the original 7.5 inch milli-sedimentation tank for the 72 hour test. The influent water was at a turbidity of 25 NTU rather than 5 NTU. The headloss is shown in graph 15 and performance 16

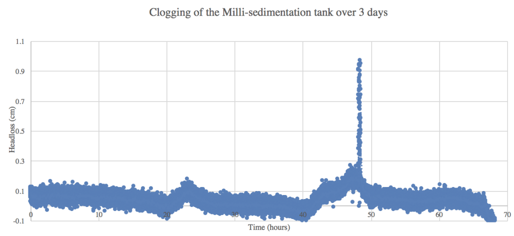


Figure 15: Headloss measured across the milli-sedimentation tank across 72 hours. The test showed consistency in headloss for the majority of the test. There was a 1 cm spike in headloss at 48 hours.

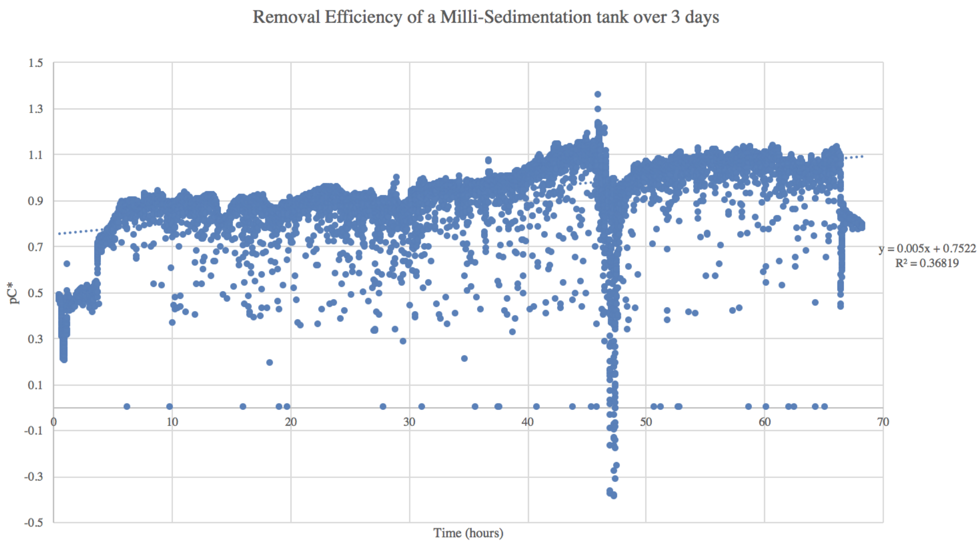


Figure 16: Performance measured across the milli-sedimentation tank across 72 hours. The test showed an increase in removal efficiency. There is a correlation with the headloss and removal efficiency plots. At 48 hours, the decrease in pC* corresponds to the 1 cm increase in headloss. This indicates filter breakthrough.

Filter breakthrough occurred at 48 hours, which is shown by the spikes in headloss and removal efficiency. With the increased NTU of 25, the apparatus removal efficiency was greatly increased. The pC* was at or near 1 for the majority of the time during the test, which is the team's goal for removal.

### Removal Efficiency measured with a larger straw diameter

Larger, clear straws were used in the following tests to track the movement of flocs in the sedimentation tank. The clear straws had a larger diameter 5.6mm, and were 8.5 inches long. The tank was calculated to need to be 16 inches long to fully settle out the flocs so the tank was built to 17 inches to fit the length of two full straws. This is compared with the 7.5 inch length 3mm diameter sedimentation tank below 17.

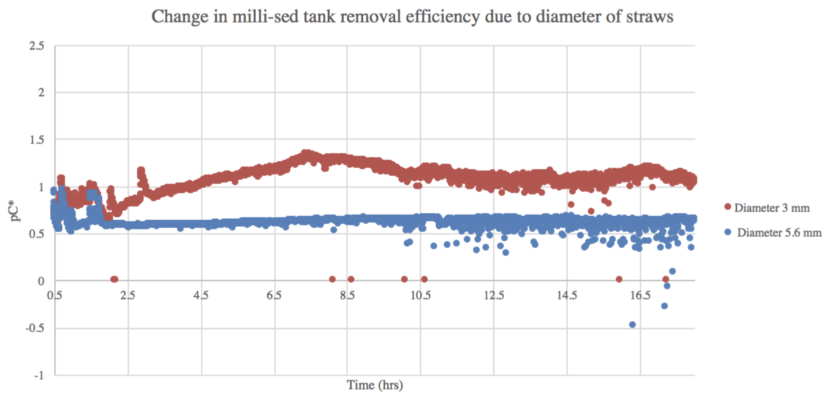


Figure 17: The two milli-sed tanks had straws with diameters of 3 mm and 5.6 mm. The 3mm straw showed increased pC* over the larger diameter. Failure time was relatively similar. Therefore, the highest removal efficiency would come form the smallest tubes.

The filtration side of the milli-sedimentation apparatus relied on small diameter straws. When the straw diameter was increased the filtration ability of the tank is decreased. The team noticed that during the test the highest density of flocs was at the constriction between the two straws where the holes did not line up perfectly. To exploit this, the team made 2 more constrictions in the straws but cutting them in half, shown in figure 18, and ran the test again.

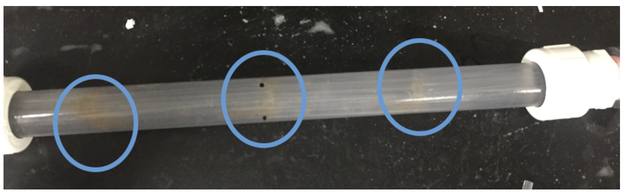

Figure 18: The constrictions in the the milli-sed tank are where the flocs congregated. The first constrictions had the highest concentration of flocs, followed by the second and the third constriction had the least number of flocs settled out. This suggests that adding more constrictions to the tank could increase its removal efficiency.

The first constriction has the highest concentration of flocs among the three constrictions. This suggests that increasing the frequency of constrictions specifically at the beginning of the tank could increase its removal efficiency, shown in graph 19.

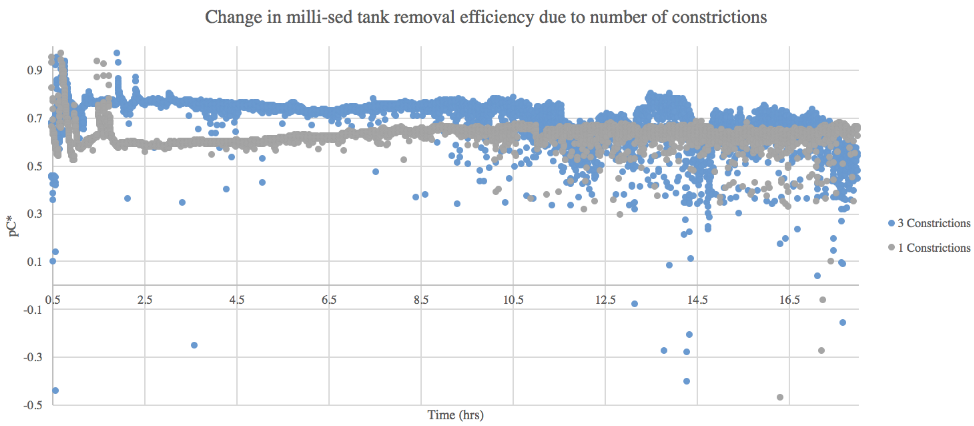


Figure 19: The two milli-sedimentation tanks had one and three constrictions, respectively.The tank with three constrictions is shown to have a higher pC*. The failure time was roughly similar for both tanks. This shows that increased constrictions could increase removal efficiency.

As shown in the StaRS research, increased constrictions increased floc removal efficiency(Chu et al., 2016). However, increased removal also lead to decreased time to failure. This is because more flocs were being settled out so that tank reached capacity faster.

# Conclusions

The team concluded that the milli-sedimentation tank works as an effective sedimentation tank. The tank removed flocs at a pC* above 1.0, which is the preferred removal efficiency for AguaClara. As shown by the comparison of removal efficiency given different straw diameters, the smaller diameter for straws, 3 mm, was more effective than the larger diameter for straws, 5.6 mm, at particle removal. This also suggested that an even smaller diameter of straws would be more effective. When comparing tests with the larger straws, it was shown that a tank with more constrictions was more effective than a tank with fewer constrictions in terms of removal efficiency. This suggested that an increased number of constrictions would increase the performance of the tank. The milli-sedimentation team determined that the tank can still improve in its capability as a filter.

# Future Work

There are multiple challenges for the Milli-Sedimentation team next semester. The team will explore whether increasing the frequency of constrictions in the sedimentation tank improves performance. The test with three constrictions in the tank revealed that floc buildup occurred the most at the first constriction. The team will test whether a tube with more frequent constrictions specifically in the beginning of the tank will improve performance more than evenly spaced constrictions as a larger buildup could occur at more frequent constrictions at the beginning of the tank. The team will also look into designing the milli-sedimentation tank at an angle. This will test whether there is an angle for the tank that prevents floc roll-up. Floc roll-up was shown to occur in the sedimentation tank when it was horizontal. The team will use PID next semester to control the influent turbidity as well. This will result in an influent turbidity closer to the target turbidity.

## References


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Whiting, J., Shen, Q., and Wu, S. (2015). Foam Filter Preflocculation Fall 2015.

Yin, J., Zu, M., and Lok, S. (2015). Foam Filter Cleaning Fall 2015.

# Semester Schedule

## Task Map

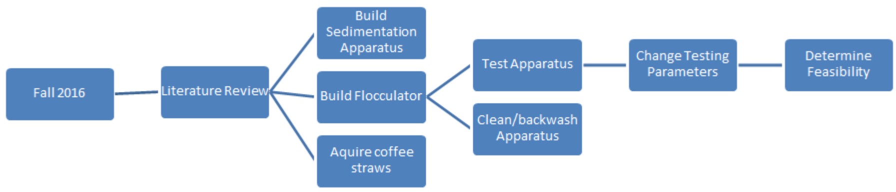


Figure 20: Task Map

## Task List

1. Literature Review (9/16) Tianyi Wang- Complete a short literature review on sedimentation with an emphasis on plate settlers and look for any resources that have used straws for sedimentation. -Completed

2. Acquire Coffee Straws (10/10) Janak Shah- Determine what kind of straws are needed for the apparatus. Preferably clear straws to observe floc movement. -Ordered

3. Build Sedimentation Apparatus (10/10) Janak Shah- Construct from a PVC pipe ( 1in) and fill the pipe with coffee straws. Test horizontal flow on the lab bench to test viability. If the horizontal flow is not viable, place the apparatus at an angle. Use Mathcad to determine the length of the pipe adequate for floc settling. -Completed

4. Build Flocculator (10/10) Jillian Whiting- Use Mathcad to design a flocculator and build it in the lab. Ensure proper floc size. -Completed

5. Testing apparatus (10/31) Tianyi Wang- Run tests using influent turbidity designs close to StaRS. Possibly use red dye to determine how flocs move through sedimentation tank and how they settle. -Completed

6. Cleaning apparatus (10/31) Jillian Whiting- Will be done after each individual test of apparatus. Use a backwash system similar to StaRS. Test high velocity bursts with apparatus and possibly observe how flocs mobilize out of the apparatus using red dye. -Completed

7. Change parameters (12/2) Jillian Whiting- Possibly change angle of the apparatus or the size of straws. Possibly build a larger scale version. -Completed

8. Feasibility Decision (12/5) Janak Shah- Determine the feasibility of implementing this design in an AguaClara plant. -Completed

**Report Proofreader:** Jillian Whiting

# Appendix

## Standard Operating Procedure

The Schematic and a labeled picture of the teams apparatus are included to help understand the standard operating procedure.

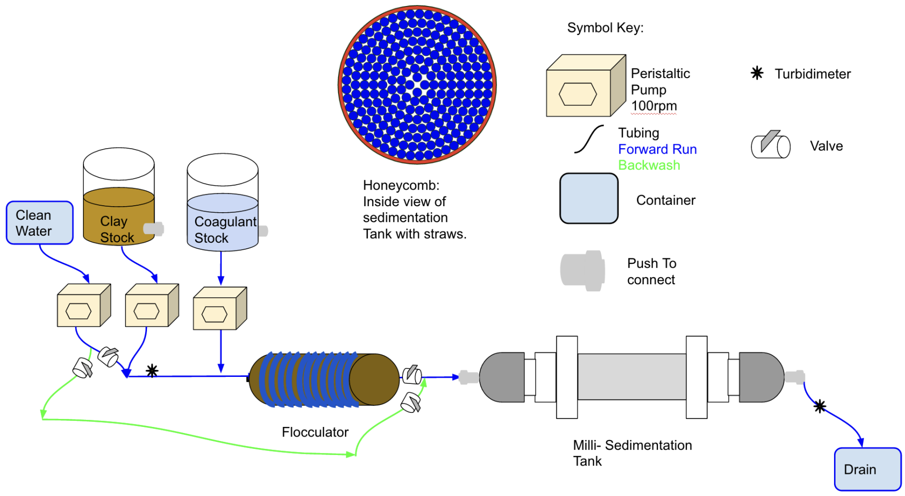


Figure 21: This Milli-Sedimentation system was used for all experiments except the sedimentation tank was replaced. The influent water is created from mixing of clay, coagulant, and tap water that are pumped in. It then flows through a turbidimeter then through a flocculator then the milli-sedimentation tank, through another turbidimeter and then out through a drain.

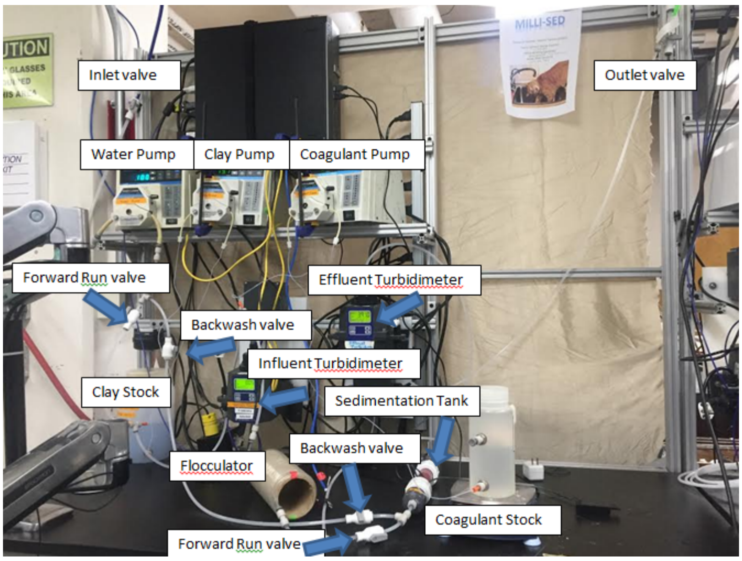


Figure 22: This a labeled picture of the apparatus from the lab.

**Materials List**

Sedimentation Tank

- 1 in diameter PVC pipe

Caps of Sedimentation Tank

- Push to connect
- Threaded Cap
- Bushing
- Quick Turn Coupling
- O-Ring

Flocculator

- 1/8 in flexible tubing

Straw Sizes

- 3mm diameter, 7.5 inch length red coffee straws
- 5.59 mm diameter, 8.5 inch length clear drinking straws

General Setup

- 4 pumps (3-100 rpm, 1-600 rpm)
- Sizes 17, 18, and 13 pump tubing
- 2 Turbidimeters
- Stirrer
- 3/8 inch hard tubing
- 1/4 inch hard tubing
- 3 L tank for clay stock
- 2- 1 L tanks for coagulant stock and flow accumulator

**Construction of Apparatus**

1. Cut 1 in diameter PVC pipe to desired length using the bandsaw.
2. Cut a 1 in diameter circular piece of screen using scissors.
3. Attach screen to exit cap, by laying it in cap. The water flow will keep it in place.
4. Put caps on entrance and exit and attach to apparatus.
5. Straws were placed in the tubes by hand. The majority were placed in together in one bunch, and then the next were added one by one in gaps or on the edges.

### Preparation of Solution

#### Clay/Humic Acid Solution per Liter:

1. Measure out, using a 200 g balance and spatula, 0.212 g of clay
2. Measure out using a 200 g balance and spatula, 0.025 g of humic acid
3. Using a graduated cylinder measure out 1 L of water
4. Add water into clay stock tank and mix in clay and humic acid.

#### Coagulant Solution (per liter)

1. Using a graduated cylinder measure out 2.125 mL of the 70.6 g/L coagulant solution in the lab
2. Using a graduated Cylinder measure out 998 mL of tap water
3. Pour both into the coagulant stock tank

### Tests

#### Forward Run

A forward run is used to test the performance of a milli-sed tank. Influent and effluent turbidity and headloss are recorded to better understand how the tank is filtering and settling flocs. From this data the pC* of the tank can be determined. The headloss correlated to how many flocs have built up in the tank.

#### Starting A Test

1. Turn on all three pumps, ensure that the clay and water pumps are on mA mode and the coagulant pump is on INT
2. Ensure that both the turbidimeters are on
3. Open the water inlet(blue) and outlet(red) valves
4. Open Forward run valves and ensure the backwash valves are closed
5. Zero the headloss
6. Turn ProCoDA to automatic operation and select the Run state.
7. Set Coagulant pump to 7.2 rpm and press start.

#### Finishing a test

1. Turn off all the pumps.
2. Close the water inlet and outlet valves.
3. Turn the turbidimeters off.

**Backwash**

Backwash is needed after every test to ensure that the sedimentation tank is clean and there are no confounding variables during a test. Data is collected during this to check that backwash is working effectively and the tank is clean.

**Conducting a backwash**

1. Turn on Water Pump and put it on INT mode
2. Ensure the effluent turbidimeter is on
3. Open backwash valves and close forward run valves
4. Open water inlet(blue) and outlet(red)
5. Turn ProCoDA to backwash state
6. Turn off after Effluent turbidity is below 1 NTU.
7. Close water inlet (blue) and outlet(red) valves
8. Turn Water pump off
9. Turn Turbidimeters off

**Appendix**

**ProCoDA Methods**

- Important States (on/Off)
- OFF - This state turns everything in the apparatus off after a test.
- Run- This state is used to turn on the pumps, turbidimeter, and stirrers during a forward run.
- Backwash- This state turns the water pump on to clean the milli-sedimentation tank after a test.
- Setpoints
- Run Time- This setpoint is how long the team wants to run a test for, so that ProCoDA will switch states to OFF after the elapsed time is greater than the run time.
- Variables (Pump speed, PID Control)
- Influent Turbidity- The variable records the turbidity of the influent water before it goes through the flocculator.
- Effluent Turbidity - This variable records the turbidity of the effluent water after it goes through the milli-sedimentation tank.
- Water Pump- This variable controls the water pump during a forward run, so that it runs at 10 rpm.

- Clay Pump- This variable controls the clay pump so that it runs at 20 rpm.
- Water Pump Backwash- This variable controls the water pump during backwash so that it runs at 50 rpm.

**Concentration Calculations**

Clay Stock

$$NTU = 1.7\frac{mg}{L}$$

$$Q_{ClayPump} * C_{ClayStock} = Q_{Plant} * C_{Plant}$$

$$Q_{ClayPump} = 0.02\frac{mL}{s}$$

$$Q_{Plant} = 0.5\frac{mL}{s}$$

$$C_{Plant} = 5NTU = 8.5\frac{mg}{L}$$

$$C_{ClayStock} = 212.5\frac{mg}{L} = 125NTU$$

Humic Acid additions to Clay Stock

$$Q_{ClayPump} * C_{HumicAcidStock} = Q_{Plant} * C_{HumicAcid}$$

$$C_{HumicAcid} = 1\frac{mg}{L}$$

$$C_{HumicAcidStock} = 25\frac{mg}{L}$$

Coagulant Stock

$$V_{LabStock} * C_{LabStock} = V_{Stock} * C_{HumicAcidStock}$$

$$C_{CoagulantStock} = 150\frac{mg}{L}$$

$$V_{Stock} = 1L$$

$$C_{LabStock} = 70.6\frac{g}{L}$$

$$V_{LabStock} = 2.215mL$$