High Rate Sedimentation (Floc Blanket)
Spring 2016

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Abstract

The High Rate Sedimentation - Floc blanket team built a sedimentation tank model with the goal of increasing the upflow velocity and decreasing the plan view area, without degrading the performance of the floc blanket inside the tank reactor.Under high-turbidity conditions, a stable floc blanket was maintained under upflow velocities from 1-4 mm/s. Two methods of encouraging floc re-circulation, viz., in-reactor lamella plates and sludge recycling, were tested to observe effects on effluent turbidity. Results indicated that neither method had a strong enough effect to fully recommend increased upflow velocity, but future testing in improved apparatus with low turbidity influent has potential.

Introduction

Sedimentation dramatically decreases turbidity in conventional drinking water treatment and is an integral part of the AguaClara process. Part of the efficiency of the current sedimentation design is derived from what is known as a floc or sludge blanket - a fluidized bed of suspended flocs, colliding in the bottom of the tank. These collisions allow for many of the lightest and smallest particles, which would otherwise be carried out in the tank effluent, to be assimilated into larger flocs which settle out during their residence in the basin.

However, floc blankets are not as effective in the AguaClara design when the upflow velocity of the water in the clarifier is greater than 1 mm/s. At this speed, AguaClara's current sedimentation tank design is by far the slowest step in the treatment process. At a velocity of 1 mm/s, the AguaClara sedimentation tank requires a residence time of 24 minutes, three times longer than flocculation, the next slowest process. The lengthy residence time translates into an allocation of plant area that, while smaller than the industry standard, is nonetheless the largest component of the treatment process.

The large size of the sedimentation tank is a major portion of the up-front construction costs for AguaClara water treatment plants; this is of prime concern since AguaClara technology is deployed in low-income communities. A sedimentation tank operating at a higher upflow velocity would be extremely beneficial. A high upflow velocity decreases the lengthy residence time of the current model of the AguaClara sedimentation tank, thus decreasing the amount of plant area needed for sedimentation. Through the effect of decreased area, expediting the sedimentation part of the water sanitation process significantly decreases start-up cost for water treatment plants, furthering AguaClara's mission of providing designs for gravity-powered and electricity-free water treatment.

The Spring 2016 team built upon the work of the Fall 2015 team and designed a bench scale model that was more representative of the geometry of the AguaClara sedimentation tank. An insert was constructed to provide a removable sloped bottom with the jet reverser and floc weir. Experiments were conducted with and without the insert and plate settlers. The team tried to achieve floc re-circulation from the floc weir through the insert and feasibility of floc re-circulation was assessed.

Literature Review

In conventional water treatment, reliable methods for sustaining floc blankets during high-rate sedimentation exists on the frontier of knowledge. High upflow velocity has been utilized in many treatment plants and floc blankets utilized in others. But, a reliable mechanism to employ both simultaneously remains unattained. AguaClara research has only just begun in the area and comparatively little is known about the combination of the two water treatment features.

Hurst 2010 an AguaClara researcher, found that the most desirable floc blankets occurred under conditions of 1.04 - 1.27 mm/s and that effluent turbidity is linearly related to height of the floc blanket with heights shorter than 45 cm. Hurst found that upflow velocities greater than optimal result in diffuse, unconcentrated blankets. Generating a concentrated fluidized bed compatible with high rate sedimentation however was not the fundamental challenge studied however, and Hurst did not test velocities greater than 2.87 mm/s.

Culp, Hansen, and Richardson (1968) reported that they used an upflow velocity of 4.4 mm/s in their pilot sedimentation tank and were able to maintain a fluidized bed, which after being established, functioned as a flocculator so that no external flocculation outside the sedimentation tank was necessary. No details were given since the main focus of their research was tube settler geometry. However, their illustrations show a horizontal flow of influent water before sedimentation, which raised the prospect that a jet-reverser might not be necessary with high upflow velocities. The modular test apparatus used here by HRS Team 1 enabled experimentation on the effects of reactor geometry under high rate conditions, but none were carried out due to time constraints.

Previous Work

The Fall 2015 team experimented with tank and plate settlers geometries using two sets of plate settlers to capture flocs, with plate settlers near the bottom of the tank and tube settlers at the top. The team conducted various experiments to analyze the geometries and to study bed fluidization. With a sand column experiment at inclination angles relative to the horizontal of 30, 45, and 60 degrees, 60 degrees demonstrated the best floc re-circulation.

After verifying that angles shallower than 60 degrees were sub-optimal for floc re-circulation, the Fall 2015 team used a tube with a vertical bottom section and a slanted top section to replicate what might happen in an AguaClara sedimentation tank. The experiments were run with various upflow velocities and coagulant concentrations. From the experiments run the team deduced that a high flow rate and low coagulant concentration is most favorable for floc re-circulation in the tank. At a 5.75 mm/s upflow velocity and a low coagulant dose of 0.25 mg/L in the column, there was a visible fluidization of the floc bed, re-suspension of the flocs in the bottom vertical section of the tube column, and flocs seemed to be rolling down and reintegrating with the floc blanket. However the bed was more diffuse than a typical blanket, and the opaque construction of the pipe elbow prevented verification of floc reintegration. The Spring 2016 team was able to view the floc activities directly with a new test apparatus and addressed the problem of reduced concentration of the blanket.

Methods and Discussion

The first goal of the team was to create a representative model of an AguaClara sedimentation tank so that various variables such as the tank bottom geometry, plate settlers and jet reverser could be modified and the effects analyzed. The Fall 2015 team's experimental apparatus was fabricated using two tube columns held together with a 45 degree elbow. The design of the Fall 2015's sedimentation model was not adjustable. The angle, spacing and shape of the settlers could not be varied after the assembly was glued together. Additionally, there was no way to install a floc recycling system to reintroduce flocs from the sludge hopper. To accommodate for these factors, the Spring 2016 team built a model in which the above parameters of the sedimentation tank could be adjusted as necessary. A modifiable model was necessary for more in-depth experimentation, and the Spring 2016 High Rate Sedimentation team selected a design aimed at maximizing ease of modification.

First Iteration: Model Design and Fabrication

Designing and constructing the model tank and insertable modules was the primary task for the first part of the semester. The first iteration included preliminary experiments carried out to test the efficiency and utility of the sedimentation tank. It was also essential to assess the flocculator efficiency and its compatibility with the tank.

Experimental Apparatus

Design Concept:
Since an AguaClara sedimentation tank's geometry does not change across its length, a geometry was chosen which enables water and floc flow through a cross-section representative of flow throughout the entire basin. Moreover, since the tank is symmetrical about its vertical axis, the flow from one side can represent the whole. Given this geometry, the Spring 2016 team designed a scale model of a half-section of the current AguaClara design with removable modules to hold plate settlers and floc re-circulation items such as the jet reverser.

The 60-degree sloped bottom of an AguaClara clarifier was replicated with an inserted bottom module angled at 60 degrees and attached to a jet-reverser and sludge hopper. The bottom module required small deviations from an exact scale model in order to meet two other constraints: visibility and accessibility of insert modules.

Visibility Constraint:

The Fall 2015 High Rate Sedimentation team observed floc movement visually and the Spring 2016 team also allowed all parts of the tank to be visible from the outside. As a result, the sludge hopper was relocated to one side of the tank from the center-line of the tank to prevent obstruction in visibility. This change did not affect the reactor and was deemed allowable.

Accessibility Constraint:

A major goal of the team was to provide easy modification through inserted modules, hence it was essential that no module interfered with another module's insertion. In an AguaClara plant, water enters the sedimentation tank through a diffuser above the bottom of the tank and is directed 180 degrees by the jet reverser so that it continues upward. However, a diffuser in the center-line of the tank would not be feasible if experimental items such as a jet reverser and stabilization plate settlers are to be added to the bottom of the sedimentation tank. To better accommodate experimental insert modules, the jet was made to come in horizontally through a slit in the side of the tank and be directed vertically by a 90 degrees bend. Since the end result is identical, a vertical line-jet of water, the change was deemed to nonetheless accurately represent the current design.

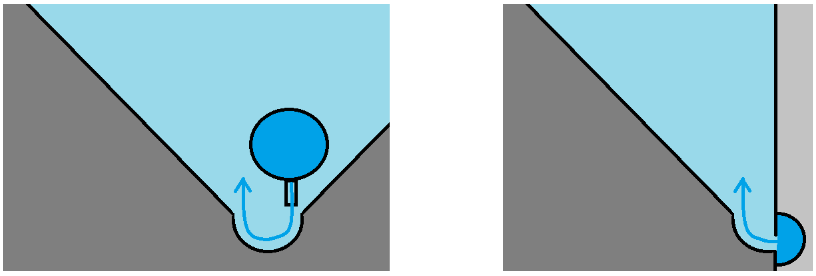

Figure 1: Comparison of water entry in stock AguaClara design (left) and scale model (right). The typical path of water entering an AguaClara sedimentation basin is through downward directed diffusers attached to an inlet pipe running the length of the basin; the water flows down and is then redirected upward by the jet reverser. The inlet pipe and diffusers however occupy the space desired for experimentation, violating the accessibility constraint, so the model was designed to have water enter from the side.

Space Constraint:

The available space for experimentation at the team's lab station was limited, and it was estimated that a flocculator built in the space would probably not be able to exceed 50 mL/s of steady floc flow, which established the size constraints of the model tank design. At 5 mm/s, that translated to an area of 100 cm^2. The width constraint came from limiting flow contraction due to inserted modules to less than an order of magnitude below the width of the tank. The height, 70 cm, was constrained by the size of available material.

Design Result:

The tank flow volume dimensions were calculated to be 20 cm x 5 cm x 70 cm. The 5 mm/s velocity goal and the 50 mL/s estimated flocculation capacity yielded a flow area of 100 cm^2 which was allocated to 20 cm x 5 cm for flow; 20 cm being the length of the tank and 5 cm being the width. The width was chosen was to minimize flow contraction due to experiment modules. The smallest available PVC sheet available was of thickness 0.15875 cm (1/16 in) and each module required two sides, implying a flow contraction of 0.3175 cm (1/8 in) at the bottom of the tank. 5 cm width was therefore chosen as the smallest integer width for which the flow contraction was an order of magnitude smaller than the width. The height was made 70 cm, the dimension that would fit onto available PVC sheets optimally and minimize the cost to $139, in an attempt to accommodate possible experiment modules like plate settlers of unanticipated size. The remaining material on the PVC sheets allowed 16.193 cm (2 3/8 in) of space outside the flow area to accommodate a sludge hopper.

Figure 2 shows the tank design drawing, and Figure 8 shows the assembled product. The drawing dimensions for the sedimentation tank and the insert are in inches.

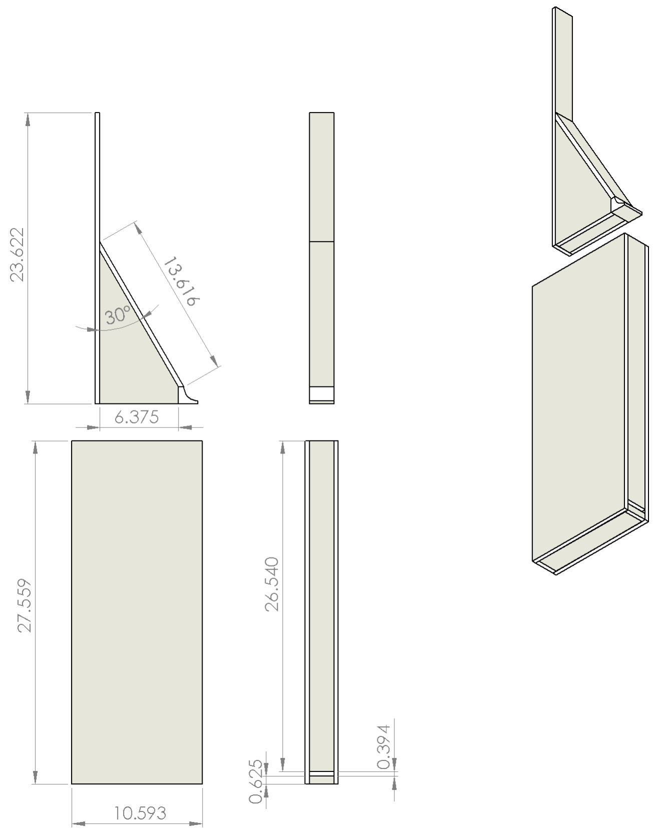

Figure 2: Side and front views of tank (below) and insert (above). The tank consists of a thin rectangle of PVC with a small slit in the bottom front to allow influent water. The insert consists of a jet reverser attached to a sloped reactor bottom and a floc weir to separate the reactor area from the sludge hopper. The insert is lowered into the tank and experimental modules lowered in on top of the insert (modules not shown).

Schematic

Figure 3 below shows the schematic of water flow through the experimental apparatus. Water entered the system through the water inlet. Next, water passed through the influent turbidimeter after mixing with the clay water solution. Then the coagulant was added to the clay-water solution. After that the water passed through the flocculator. Post flocculation water entered the sedimentation tank. From the outlet of the sedimentation tank the water passed through the effluent turbidimeter and then exited the system.

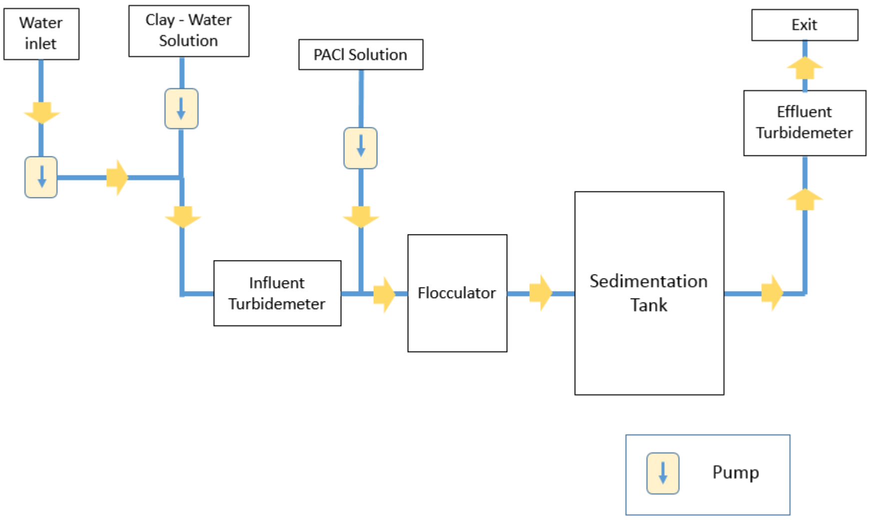

Figure 3: Schematic of experimental apparatus.

Materials

The tank was built with clear PVC sheeting of thickness 0.9525 cm (3/8 in). The thickness was chosen because a previous subteam used sheet of 0.9525 cm thickness to construct a filtration apparatus of similar dimensions and was able to sustain the hydro-static stress of water on the tank walls. Though more expensive, clear PVC was used to meet the visibility constraint, so that the floc movements could be observed in the tank without cameras or other sensor equipment. The jet reverser was built using a PVC pipe of thickness 0.635 cm (1/4 in) and diameter 7.62 cm (3 in). Vinyl weatherproofing tape was used on the sides of the reactor insert.

Construction

The tank body and the insert were marked on the PVC sheets. Then the parts were cut on a table saw with help of the people from Cornell shop. The parts of the insert were sanded to give smooth surfaces for avoiding leaks and floc accumulation. The parts were cemented together with primer and PVC glue. As the glue was not enough for holding the tank together and water-proofing, the tank was welded using the PVC welding rod available in the lab.

The insert was put together with primer and PVC glue. All the edges of the insert that came in contact with the sedimentation tank were covered with a compressible foam tape. As the tank was filled with water, it expanded due to the hydro-static pressure on the walls. So to account for this expansion a compressible foam was used that prevented the flow of flocs and water across the insert. Two holes were drilled in the insert as an inlet to fill the insert with water and outlet for air.

The inlet for water into the tank was made out of a clear PVC pipe. The pipe was capped on both sides with a fitting for water outlet. An opening was cut into the pipe to work as inlet. The width of the opening was equal to the width of the tank. The pipe was then hot-glued onto the tank with the opening facing another opening in the tank. The water flowed in through both the ends of the pipe, from the openings into the tank. An outlet was drilled for water to go out on the sludge hopper side of the tank. Figure 4 and figure 5 below show the inlet from different angles. Figure 6 shows the front and side view of the inlet.

Figure 4: Top view of the inlet after being glued to the tank.

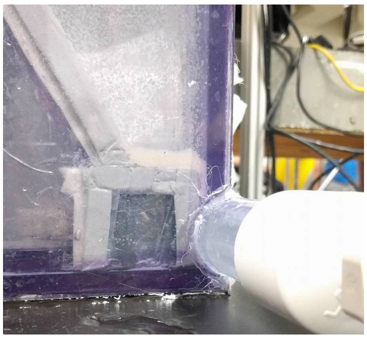

Figure 5: Side view of the inlet

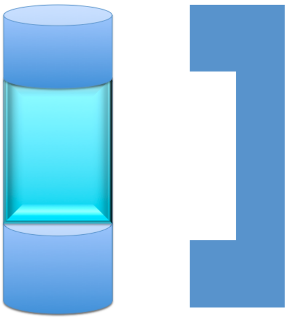

Figure 6: Front view of inlet (left) and side view (right)

For the jet reverser, a quarter section of 5 cm PVC pipe was cut to give water a 90 degree turn. The pipe piece was attached to thin PVC sheets on all sides except the front for support. The side view of the reverser can be seen in figure 7 below.The jet reverser was then attached to the insert.

Figure 7: Side view of jet reverser. Pale blue is the pipe section, the surrounding is thin PVC sheet sections for support

The figure 8 shows the tank with the insert after complete fabrication.

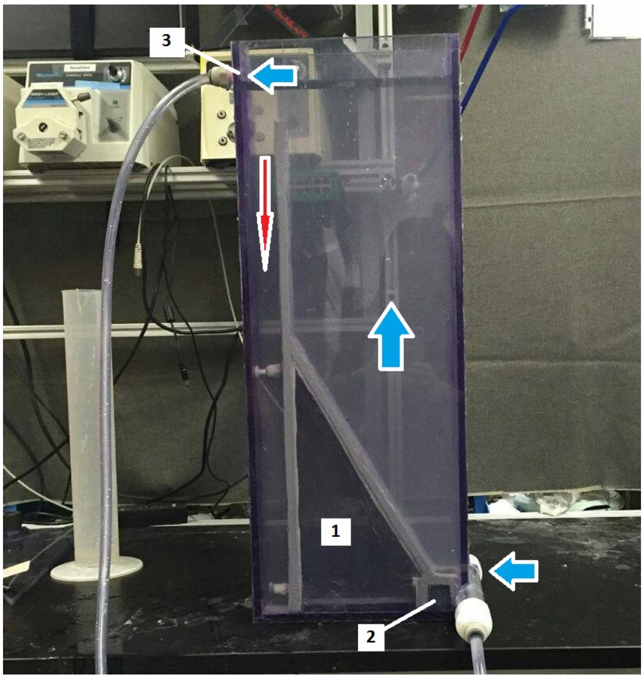

Figure 8: Tank with the insert (1) and jet reverser (2) and outlet (3). Blue arrows show water entering, rising through the tank and exiting, the red arrow points into the sludge hopper where flocs will fall and consolidate.

Complications in construction

The parts had to be cut very precisely, so that insert fitted tightly in the tank. The compactness was important for preventing water and floc movement across the insert and floc weir. The table saw used had a precision of 1/16th of an inch. So to ensure exactness, the dimensions of all the parts were rounded off to closest 1/16th of an inch before cutting. Also, a few parts had to be shaved and sanded after cutting to complement all the other faces of the tank perfectly, including the bottom of the insert which required milling in the CEE machine shop to get a flat surface.

Waterproofing also caused some problems. The tank was first constructed with PVC glue, which provided strong structural strength but allowed water to penetrate through at many points, so a plastic welder was employed around the edges. This reduced the leaks but did not eliminate them, and the team went through several welding iterations before the tank finally was watertight. Even after this however, subsequent modifications introduced pinhole leaks which required the apparatus to be situated inside a drip-pan.

The insert also needed to be snug in the tank to prevent water from flowing horizontally instead of vertically. However the bare PVC-on-PVC contact did not sufficiently impede horizontal floc movement. Rubber tubing was considered as a liner to seal against lateral flow, but the rubber did not adhere well to the PVC, hence foam strips were tried. This could be easily glued to PVC using hot glue, but it was found that the friction against the wall was excessive and the force required to move the insert into position was deemed likely to cause damage to the apparatus. The friction problem was solved by coating the foam in packaging tape, which slides easily along wet PVC but does not substantially inhibit the sealing action of the foam.

Procedure

The high rate sedimentation - Plate Settlers team constructed a flocculator for the flow rate of 50 mL/s. The design methods are specified in detail in the high rate sedimentation - Plate settlers team report 2016 .The flocculator was constructed using a 2.2 cm (7/8 in) diameter tubing. 27.6 m of the tubing was wrapped around two 15.2 cm (6 in) pipes in a figure of eight for better circulation and to avoid settling of particles in the flocculator. The energy dissipation rate was calculated to be 8.729 mW/kg for this flocculator. To ensure the flocs would not settle down in the flocculator, the orientation of the flocculator was kept horizontal, shown below in figure 9. Afterwards, the stability of the floc blanket was tested at two different upflow velocities - 1 mm/s and 2 mm/s. However, a smaller flocculator was used for 1 mm/s upflow velocity because the bigger flocculator was designed for higher upflow velocity and produced almost no flocs at 1 mm/s.

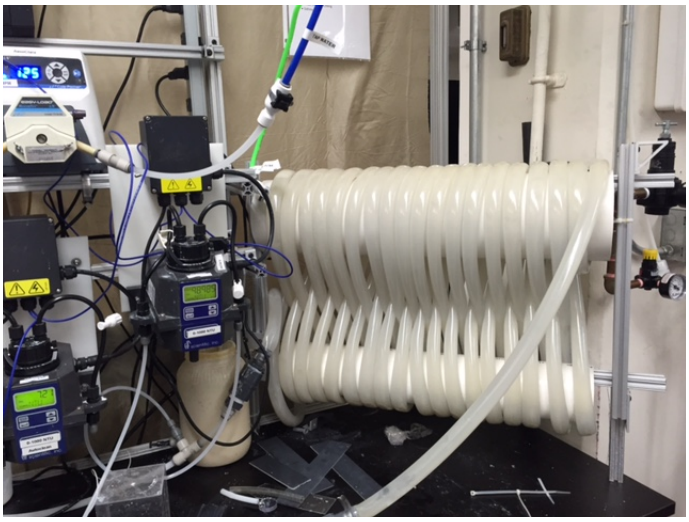

Figure 9: Flocculator in the horizontal orientation

Results and Discussions

After successfully getting the flocculator to consistently form flocs and feeding them into the sedimentation tank inlet at upflow velocity of 2 mm/s, a floc blanket began to develop in the sedimentation tank. Two distinct layers of flocs and clear water could be seen as in the figure 10.

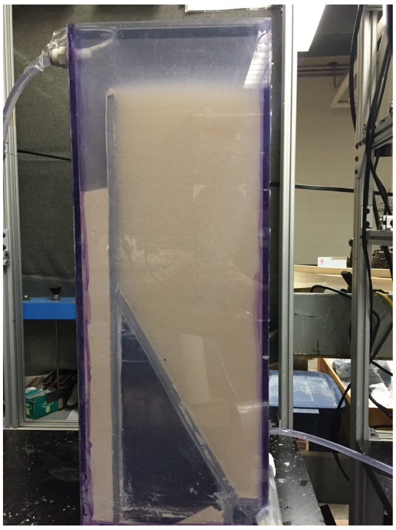

Figure 10: The floc blanket that formed in the sedimentation tank at an upflow velocity of 2mm/s.

The floc blanket grew until it reached the height of the top of the floc weir. Once the blanket reached that height, smaller flocs either wasted into the sludge hopper or exited the sedimentation tank through the pipe outlet at the top of the sedimentation tank. The floc blanket also seemed to be fairly stable and thick at 2 mm/s. The desity change was observed by shining an LED light through the tank and observing the change in opacity and color. At steady-state, the turbidity of the floc blanket was measured to be 4,300 NTU using a hand-held turbidimeter. The high turbidity of floc blanket is desirable because the denser fluidized floc bed intercepts incoming clay particles and reduces the turbidity of the settled water.

Second Iteration

Since fabricating and leak-proofing the tank had consumed more than the expected amount of time, it was deem imprudent to use the remainder of the semester fabricating a watertight tube settler array to simulate the top section of an AguaClara clarifier. Hence a sample was removed via a small number of tube settlers and treated as representative of a full array.

Two tubes of identical capture velocity but different length were used, one operating at approximately three times the flow rate of the other. Two tubes of different lengths were used to test the robustness of AguaClara settler theory under high-flow conditions. The model dictates that both tubes should produce the same quality of effluent, and the team wanted to verify that before generalizing the results.

Experimental Apparatus 2

Tube Settler

Two 1.5cm inner diameter tube settlers of different length were added into the top of the tank at a 60 degree angle and connected to separate pumps. The longer tube was 0.965m (38 in) and the shorter tube was 0.279 (11 in), and the pump speeds were set to provide a 0.12 mm/s capture velocity for both tubes using the AguaClara design equations.

ProCoDA

ProCoDA was used to maintain the influent turbidity at 100 NTU. The Proportional Integral Derivative (PID) control regulated the clay pump speed to keep the influent turbidity constant. The values for P, I and D were set to P = 0.05, I = 0.12 and D = 0 to get the constant influent turbidity of 100 NTU.

Procedure 2

Experiments were designed to access the floc blanket concentration. Floc blanket concentration was measured at three velocities - 1mm/s, 2mm/s and 3mm/s. At each velocity, three experiments were carried out.

1. Assessing the floc blanket concentration in the tank without plate settlers. Figure 10 shows the floc blanket formation without plate settlers.
2. Assessing the floc blanket concentration with the plate settlers in the top part of the tank. Figure 11 shows the floc blanket in the tank with the plate settlers in the top.
3. Assessing the floc blanket concentration with plate settlers in the bottom part of the tank.

Figure 11: The floc blanket that formed in the sedimentation tank at an upflow velocity of 3mm/s with plate settlers in the top part of the tank

The table below shows the experiment conditions at 1mm/s, 2mm/s and 3mm/s upflow velocity.

-	1mm/s	2mm/s	3mm/s
Influent Water Flow Rate (mL/s)	11.36	17.88	28.4
Influent Turbidity (NTU)	100	100	100
Influent Coagulant Dose (mL/s)	0.0101	0.0158	0.0291

To decrease the floc blanket formation time, sludge from the floc hopper was collected and was then added to the beginning of the flocculator to re-enter the sedimentation tank.

For each experiment, floc blanket concentration and effluent turbidity were measured. Floc blanket concentration was measured using a hand turbidimeter. A 1 mL sample was diluted by a factor of 20 to 50 (depending upon the need of dilution as maximum turbidimeter reading is 1100 NTU) and the turbidity was measured. The turbidity of the effluent exiting from the tube settler was continuously monitored by ProCoDa and to determine the effluent turbidity an average of 10 minutes of turbidity values, after reaching a steady state was taken.

Results and Analysis 2

Tube Settlers

The shorter tube settler with the lower flow rate was unable to be used for comparison because its flow requirements were below the effective sensitivity of the inline turbidimeter. Instead of flowing past the sensor, flocs settled on the bottom of the pipes and inside the turbidimeter. Because of this, a comparison between the two could not be made and the long settler was used solely.

Clarifier Performance

The floc blanket concentration varied with the upflow velocity and the presence and position plate settlers. The results were plotted to compare the effect of the velocity and plate settlers on the floc blanket concentration.

The graph below shows the change in floc blanket concentration with the position of plate settlers. It can be seen that the floc blanket concentration was optimum with plate settlers in the bottom.

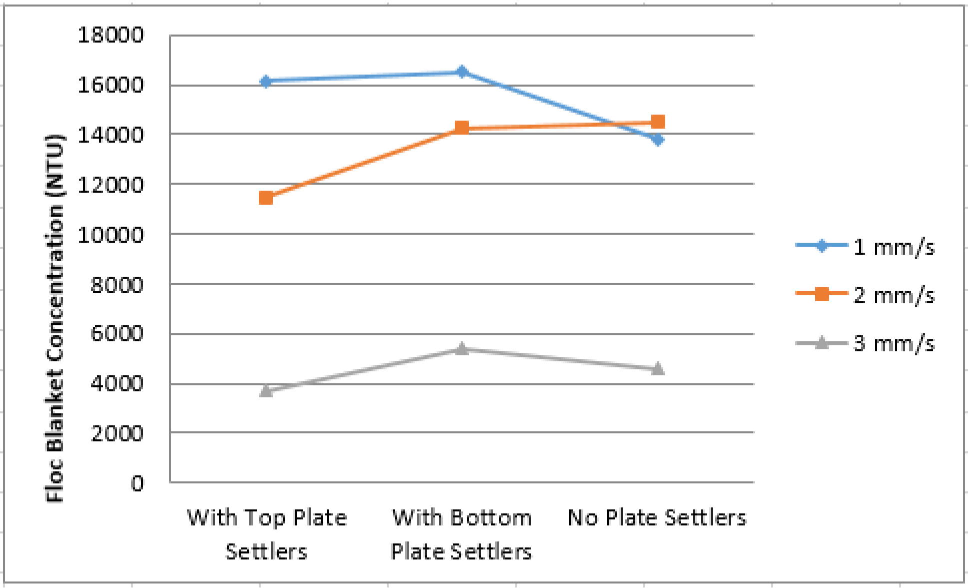

Figure 12: The variations in floc blanket concentration with top plate settlers, with bottom plate settlers and without plate settlers.

Across all of the experiments the floc blanket concentration was the most dense with plate settlers at the bottom of the tank. There was a visible decrease in floc blanket concentration when plate settlers were removed from the sedimentation tank. Plate settlers decrease the upflow velocity by adding a horizontal component. As a result, more flocs are able to settle thus increasing the concentration of the floc blanket. This is evident in Figure 11; there is a general downwards trend mirroring plate settlers were in the tank versus when they were removed.

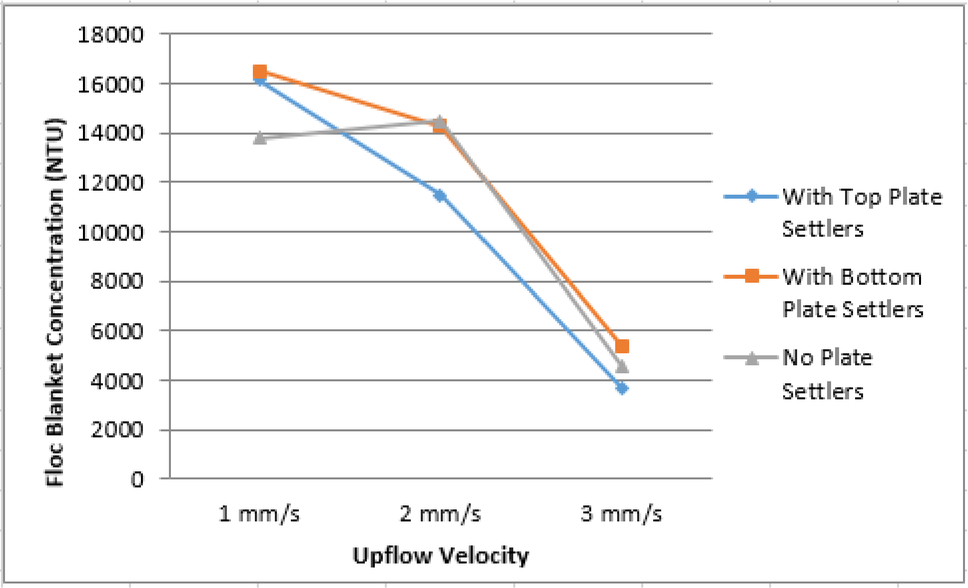

Figure 13: The variations in floc blanket concentration at 1 mm/s, 2 mm/s and 3 mm/s upflow velocity.

As seen in Figure 12 above, the floc blanket concentration decreased as the upflow velocity increased. This was expected; the ability of flocs to settle down to strengthen the floc blanket is greatly inhibited by a higher upflow velocity.

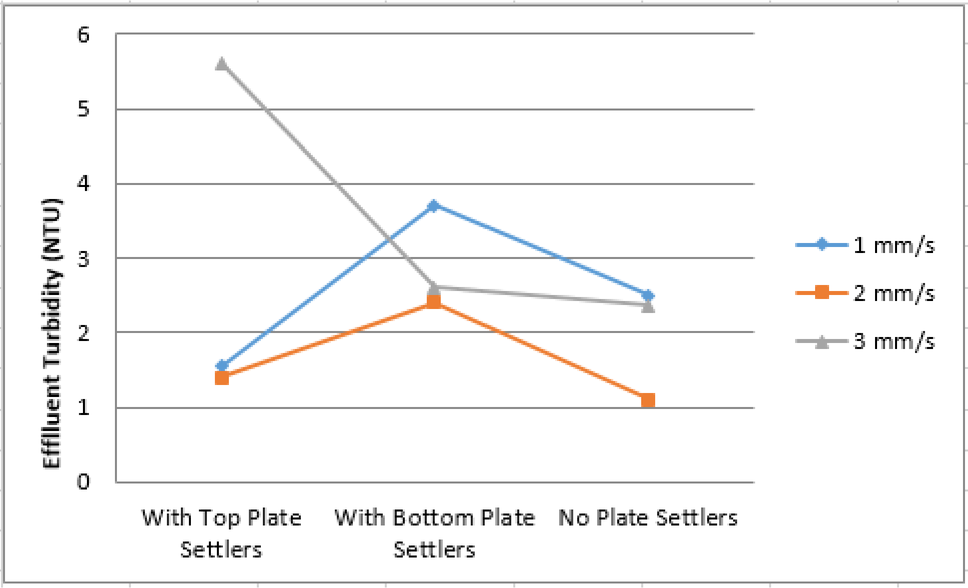

Figure 14: The variations in effluent turbidity with top plate settlers, with bottom plate settlers and without plate settlers.

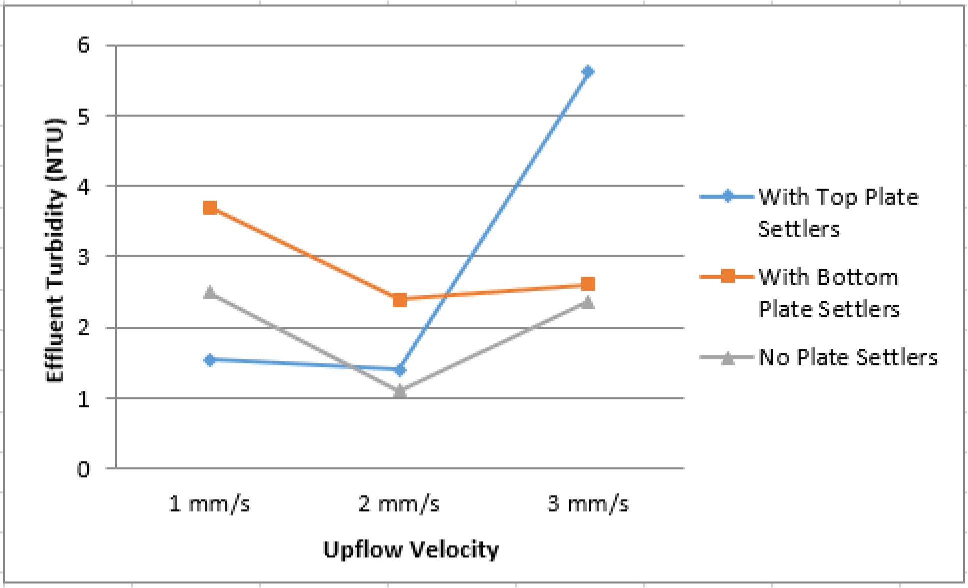

Figure 15: The effluent turbidity at 1 mm/s, 2 mm/s and 3 mm/s upflow velocity. The effluent turbidity was measured at these upflow velocities with top plate settlers, with bottom plate settlers and without plate settlers in the tank.

Generally, effluent turbidity increased at high upflow velocities (3 mm/s) regardless of the presence or absence of plate settlers in the sedimentation tank. This increase was expected because at higher upflow velocities flocs do not have adequate time to settle out and as a result they are likely to wash out in the effluent. The effluent turbidity was the lowest at a 2 mm/s upflow velocity with and without plate settlers. It is not exactly clear why this was the result.

Third Iteration

A third iteration was carried out to assess how the re-circulation of the sludge affected the floc blanket concentration and effluent turbidity.

Procedure 3

The first experiment from iteration two, assessing the floc blanket concentration without plate settlers, was duplicated without adding sludge at the beginning of the flocculator. All the inputs from the iteration two were kept constant except re-circulation of the sludge.

Again the floc blanket concentration and effluent turbidity were measured. The obtained data was then compared with data collected from iteration two to see the effects of adding the sludge.

Results and Analysis 3

The results were plotted to analyze the changes in floc blanket concentration and effluent turbidity. The figure 16 shows the floc blanket concentration decreased with increasing upflow velocity as expected. When these results were compared with the results in figure 13, it was inferred that sludge re-circulation increased the floc blanket concentration by at least a factor of two. When the effluent turbidity in fig 17 was compared with data in figure , it was observed that the for 1 mm/s the effluent turbidity was decreased, for 2mm/s it was close to the value from iteration two and for 3mm/s the effluent turbidity decreased. The results were as expected, inversely proportional to floc blanket concentration.

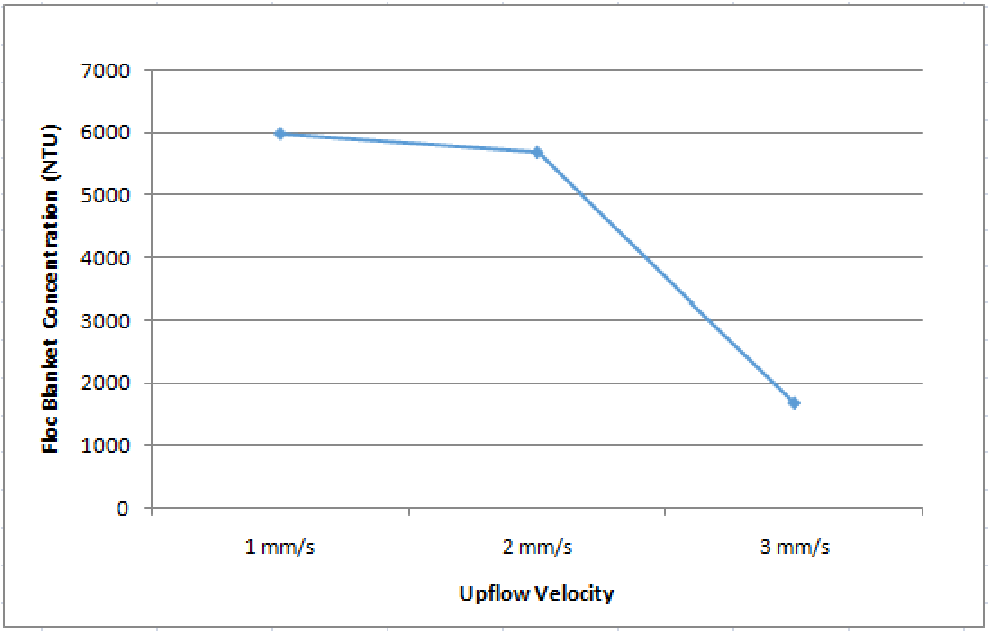

Figure 16: The floc blanket concentration at 1 mm/s, 2 mm/s and 3 mm/s upflow velocity without plate settlers and sludge re-circulation

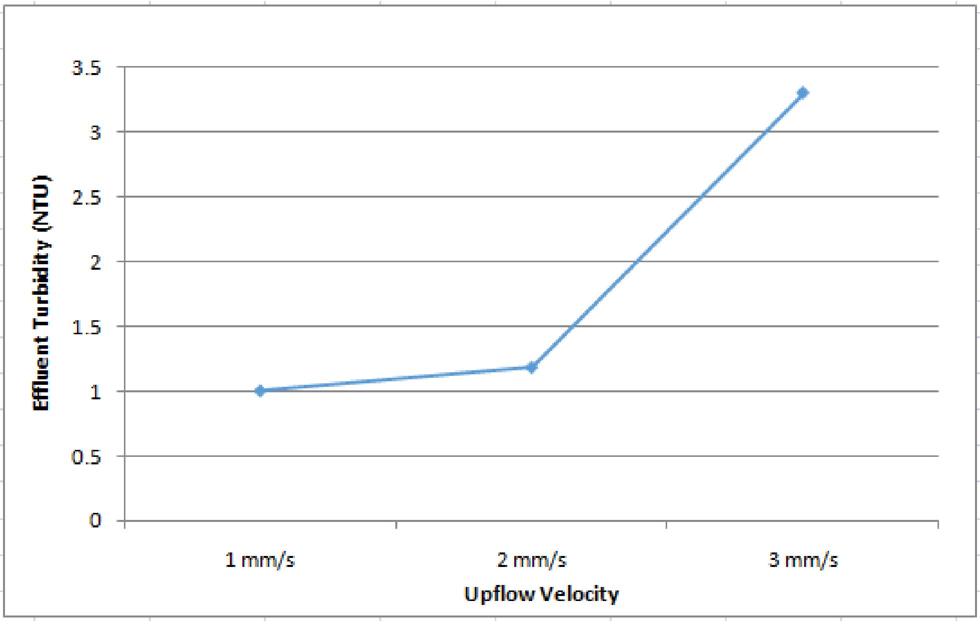

Figure 17: The effluent turbidity at 1 mm/s, 2 mm/s and 3 mm/s upflow velocity without plate settlers and sludge re-circulation

Conclusions

The most surprising discovery, that of super-dense flocs that are found when the turbidity is above 10000 NTU that appear to have a different fractal dimension, presents a powerful potential opportunity for AguaClara sedimentation technology. While investigating the flocs' creation is a task for future teams researching flocculation, the effect on floc blanket concentration and the resulting effluent turbidity is massive. Nothing known to the members of the High Rate team produces such a dramatic improvement in performance under high upflow conditions. Even if high rate sedimentation is never implemented into the AguaClara model, super-dense flocs can be researched as a way to improve performance at the conventional velocity.

The High Rate Sedimentation team mostly confirmed the typically-held belief that more dense floc blankets are associated with lower effluent turbidity, but extended the observation into two different geometries and velocities than are typically seen in an AguaClara plant, namely velocities greater than 1mm/s and with both low and high in-blanket settlers. That floc blanket concentration greatly affects effluent turbidity even as upflow velocity increases confirms the hypothesis that if high-rate sedimentation is incorporated into the AguaClara model that the state of the fluidized bed will be responsible for most of the contaminant removal.

The exception to the general association of density and performance that was identified in the exceedingly high floc-blanket concentration at 1mm/s, in which effluent turbidity began to rise, also is suggestive. It implies that there may be an ideal density threshold, beyond which floc consolidation in the reactor is counterproductive. Hence the idea of a density limit is introduced to the AguaClara sphere of knowledge. If further experimentation yields fruit for floc blanket density augmentation, especially for the current AguaClara standard velocity of 1mm/s, the ideal density threshold would be a controlling design parameter for future plants.

Future Work

Tolerance to Dissolved Organic Material

Since the effluent turbidity at 2mm/s was consistently similar or better than other upflow velocities, including 1mm/s, further research into real-world application of 2mm/s flow is the next logical step. However in real treatment plants the water contains significant amounts of organic material, which interferes with coagulation, hence experiments which include organic matter in addition to clay will demonstrate whether the trend extends to real-world application.

Low Turbidity Testing with Better Apparatus

Due to the absence of a full array of tube settlers, running at low influent turbidity is not possible in the current apparatus. However testing at low influent turbidity is critical since established AguaClara plants typically experience conditions about an order of magnitude less than the conditions tested. The addition of a settler array will enable a full simulation of the AguaClara sedimentation basin and conclusively support or disprove the efficacy of high rate sedimentation in a realistic setting.

Super-Dense Floc Generation

Super-dense flocs have a profound impact on effluent turbidity and the mechanics behind their creation needs to be investigated by a flocculation team. Optimizing the AguaClara flocculator to produce these type of flocs would greatly densify the floc blanket and by extension likely improve performance.

References

Culp, G., Hansen, S., and Richardson, G. (1968). High-Rate Sedimentation in Water Treatment Works. *Journal (American Water Works Association)*, 60(6):681–698.

Hurst, M. (2010). Evaluation Of Parameters Affecting Steady-State Floc Blanket Performance.

Lishan Zhu, Sidney Lok, Y. Y. A. C. (2016). High Rate Sedimentation|Plate Settlers.

Semester Schedule

Task Map

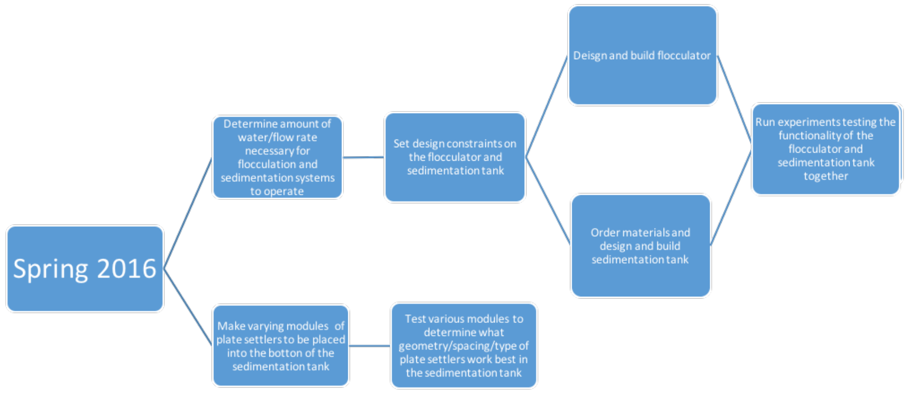

Figure 18: The task map illustrated above is the comprised of the work the Spring 2016 subteam will be doing over the course of the semester.

Task List

1. Determine the maximum flow rate (02/08/16 - 02/14/16) - Oge. Determine the maximum amount of water/flow rate available that we can provide for our flocculator and sedimentation tank systems. - Completed.

2. Order Material (02/08/16 - 02/14/16) - Isha. Order materials (clear PVC sheet) from McMaster Carr for sedimentation tank. - Completed.

3. Determine tank dimensions (02/15/16 - 02/21/16) - Vanessa. Investigate possible dimensions for the flocculator and sedimentation tank. - Completed.

4. Complile Mathcad File (02/15/16 - 02/21/16) -Josiah. Compiling all MathCad files into one MathCad document. - Completed

5. Design the flocculator and sedimentation tank (02/15/16 - 02/28/16)- Oge. Design the flocculator and sedimentation tank based on determined dimensions. Make a design drawing for the sedimentation tank. - Completed.

6. Fabricating the sedimentation tank (03/06/16 - 03/19/16) - Vanessa. Construct the sedimentation tank for the experiments. - Completed

7. Fabricating the flocculator (03/20/16 - 03/26/16) - Isha. construct the flocculator for running the experiments. - Completed.

8. Test the flocculator (03/27/16 - 04/02/16) - Isha. Test the efficiency of the flocs. - Completed.

9. Design modules (04/03/16 - 04/13/16)- Josiah. Design modules of plate settlers to be placed in the bottom part of the sedimentation tank. - Completed.
10. Fabricate modules (04/03/16 - 04/13/16) - Oge. Construct the modules of plate settlers based on previous week's design. - Completed.
11. Design experiments (04/03/16 - 04/13/16) - Josiah. Design experiments to assess the working of sedimentation tank by increasing upflow velocity upto factor of five. - Completed.
12. Run experiments (04/14/16 - 04/20/16) - Oge. Run experiments to monitor water flow in the tank. - Completed.
13. Modify the modules (04/21/16 - 04/24/16) - Isha. Modify the modules in the tank according to the data collected from week 9.
14. Run experiments (04/25/16 - 05/07/16) - Vanessa. Continue to run experiments after modifications of modules. Make appropriate adjustments after every experiment.
15. Analyze the data (05/08/16 - 05/11/16) - Josiah. Analyze data collected from the experiments and write the conclusion.

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