Sedimentation Tank Hydraulics Final Research Report

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Abstract

The sedimentation tank hydraulics team this semester focused on optimizing the floc hopper. Our main goal was to learn more about the floc hopper geometry and reasons for floc blanket failure. We started the semester by looking at the vertical sedimentation velocity. This velocity is controlled by the flow into the tank and effects how fast the particles settle. If this velocity is too high or too low, the sedimentation tank will not form a proper floc blanket.

We also looked into how the plan view area of the floc hopper would effect the floc blanket formation and performance. Changing the size of the floc hopper effects how much of the area allows for up-flow of the water and how much captures the flocs. In our current experiments we are trying different sizes at different wasting rates. We are looking for a size and rate that keeps the plant running efficiently, meaning the least amount of water wasted while keeping the water leaving the plant clean.

One of the ideas we are working on is continuous wasting of the flocs. The idea behind this is to allow for constant removal of flocs instead of collecting the flocs and then manually opening a valve to let them leave the tank. When the wasting rate is optimal, the flocs will be allowed to compact before they are removed so that the least amount of water is lost in the process. Our last experiment looked at finding the proper wasting rate where the rate of particles flowing into the floc hopper is the same as the rate at which the particles are being removed.

Part I

Literature Review

To prepare for our experiments the previous research done with sedimentation tank hydraulics was reviewed. Since we are repeating the hindered sedimentation velocity experiment from last semester, we read over that experiment in great detail. One of the conclusions made in that experiment was that the first 30 seconds was not long enough for finding the velocity because the computer program used to analyze the video was not sensitive enough to detect the small movement. We are therefore going to look at the sedimentation over a longer period of time. We decided on 10 minutes since the majority of the settling was completed by then. We are going to perform the experiment at the same 3 velocities previously used, .6mm/sec ,1.2mm/sec , and 1.6mm/sec. We are using a different insert so we will see if the other insert changes the outcome of the experiment. We also hope to study the behavior of the floc blanket as it settles to see if it gives any more insight into floc bed characteristics.

Previous AguaClara experiments conducted last spring looked at the idea of continuous wasting. In continuous wasting, sludge is continuously removed from the floc hopper. Since they are being continuously removed, the flocs are not given as much time to settle as in pulse wasting. Therefore suspended flocs were being removed instead of consolidated sludge. To minimize the wasting of clean water, the wasting rate should equal the rate at which flocs are flowing over the weir. This wasting rate is also a function of the influent rate and influent turbidity as well as the concentration of flocs in the floc blanket.

The previous team discovered that the overall problem with continuous wasting is that a high wasting rate will leave little time for flocs to condense and the waste pump will be drawing out clean water that could have been used for drinking. However, a low wasting rate can cause a floc blanket failure where flocs flow up into the tube settlers and eventually into the effluent. Therefore in our experiment testing different weir sizes, it will be important to find a balance where minimal water is being wasted and there is a high concentration of flocs in the weir, but not to the point where the floc blanket is in failure.

Part II

Introduction

The sedimentation tank is used to form a floc blanket in the bottom of the tank and allow clean water to flow out the plate settlers at the top. The floc blanket that forms is a dense area of particles and works like a filter to catch smaller particles that might not settle on their own. The jet reverser continuously resuspends the flocs so they do not build up in the bottom of the tank. The floc blanket is continuously removed from the sedimentation tank so it does not build up and clog the tank. Removing the floc blanket is accomplished by installing a floc weir that allows the floc blanket to flow over the weir and out the sludge drain.

Optimizing the floc blanket and floc weir is an important part of reducing excess sludge and continuously allowing clean water to flow out of the tank. When optimized it also reduces the amount of water wasted by further concentrating the flocs in the weir. We will be working on optimizing the floc hopper geometry for the best floc extraction. The best geometry will be one with the highest floc hopper concentration and the lowest optimal continuous wasting rate.

Another problem currently encountered in Aguaclara plants is detection of floc blanket failure before it occurs. Therefore we will be working on identifying floc blanket failure conditions so that a method can be constructed to avoid those failures in the future. This will allow the team to give operators the ability to recognize floc blanket failure before it occurs so operators can always be providing the best possible water to the community.

Another aspect of the sedimentation tank that is relevant to our current research is the buildup of sediment in the tank. Currently the flocs flow over the floc weir and settle for a while before being removed. This can cause the tank to have a buildup of condensed flocs over time. A buildup of flocs must be removed by shutting down the whole plant in order to clean the tank. Using continuous wasting instead of the current method could eliminate the buildup of flocs and therefore eliminate the necessity to shut down the plant to clean the tank. Our research will look into the possibility of continuous wasting as an option for future plants.

Part III
Methods

Hindered Velocity Experiment

For the hindered velocity experiment we set the upflow velocities at 3 different rates to see how this would affect the settling velocity. The three upflow velocities we chose to test were 0.6mm/sec, 1.2 mm/sec, and 1.6mm./sec. We set the alum dose at 45mg/L and the influent turbidity at 100 NTU. The plant is allowed to run until an acceptable stable floc blanket is formed. At this point the influent pump is turned off and the floc blanket is allowed to settle. The settling is recorded using the LabVIEW program with the camera set at 5 sec/shot for eight minutes. The pictures are then compiled into a video which is used to analyze the settling velocity. LabVIEW measures the actual height of the floc blanket at each 5 sec interval which allows us to calculate the hindered sedimentation velocity.

Floc Hopper Geometry Experiment

We constructed three different floc wiers, each having a plan view area of 10%, 15% and 20% of the sedimentation tank plan view1. The angle of the floc weir was kept constant among the three floc wiers, which results in varying volumes. The plant was run at 1.2 mm/sec, 45mg/L alum dosage and an influent turbidity at 100 NTU. A floc blanket is allowed to form and flocs are allowed to accumulate in the floc hopper. Once the floc hopper is filled, the wasting rate is set to 40 mL/min and is then decreased in incremental steps, allowing sufficient time for the floc bed to attain a steady state. Once the height of the floc bed and flocs in the hopper are constant, the wasting rate is recorded. After compiling all the data, the video analysis software is used to calculate the concentrations in the floc bed and floc hopper.

Figure 1: Floc Hoppers of Various Plan Views

Figure 2: Sedimentation Tank

A few changes were made to our setup. The first change is that we decreased our alum dose. After speaking with Monroe and looking at our flocs, he believed that our alum dose was too high. Our flocs looked larger than they should be, which suggests that the alum dose was too high. Monroe believed we could decrease our dose down to 15mg/L, so we have operated at this alum dose since. We have also decided to start running the tube settlers. This allows us to see how running those may affect the motion of the flocs in the sedimentation tank. It will also allow us to find the plant effluent turbidity. One discovery we made while running these experiments is that there was an area of the sedimentation tank that had a dead zone. In this area the flocs did not have a distinct upwards or downwards motion. The dead zone was right below the floc hopper. We got rid of this dead zone by attaching foam to the bottom of the floc hopper to block the flocs from entering that area 3.

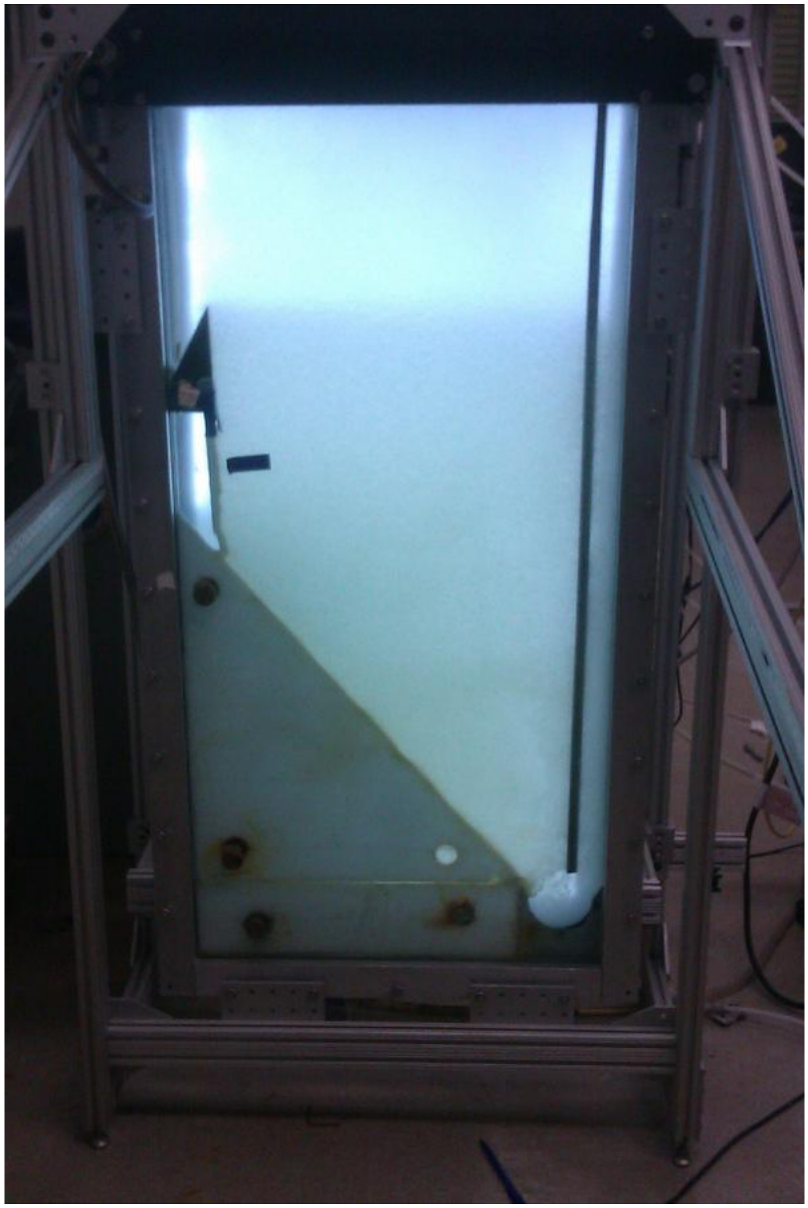


Figure 3: Revised Sedimentation Tank with working Floc Blanket

Constant Wasting Rate

During this semester, we have run three different wasting rates (15ml/min, 25ml/min and 30ml/min) for different plan view areas (10%, 15% and 20%). The floc hopper often goes empty within 30 to 60 seconds under these wasting rates. After the floc hopper empties, the wasting tube removes flocs right after flocs reach the bottom of the floc hopper which indicates the floc hopper is not compressing the flocs as intended. The concentration of the flocs sucked out by the wasting tube is the same as the concentration of flocs on the top of the floc blanket.

In order to make the floc hopper compress flocs and minimize the workload for the plant operator, we decided to run a low constant wasting rate experiment on the 10% plan view area floc hopper. The minimum flow rate we can get from the pump in our lab is 1.3ml/min, so we selected 1.5ml/min as our primary constant wasting rate. We then changed the wasting rate from 1.5ml/min to 15ml/min in small intervals. We also did experiments at wasting rates of 2.0ml/min and 2.5ml/min.

Part IV
Analysis

1 Hindered Velocity Experiment

Based on the previous teams' results and hypotheses, we have a good idea of what we expect the data to show. Assuming that the height of the floc blanket remains constant, then the upward velocity should equal the sedimentation velocity of the flocs. Therefore, when the upward velocity goes to zero the downflow velocity should be the same as the upward velocity. The team from Spring 2012 actually discovered that the hindered sedimentation velocity was lower than this theoretical velocity, leading them to believe that wall effects were affecting the speed. Given this result, we expect that our data should fall close to the previous team's results, or at least be lower than the upflow velocity.

Unfortunately, when analyzing our images, we noticed that we could no longer locate our background images needed for analyzation. We took new background images, but because of possible camera movements, these may not provide the best images for analyzation. Therefore, our analysis will be different from what we originally expected, but we hope to be able to interpolate some sort of trend line from which to draw conclusions. The 0.6mm/sec experiment had images taken at 1 image/5 seconds while the other two experiments had images taken at 1 image/30 seconds.

Using rough interpolation we found that the the sedimentation velocity for 0.6mm/sec upflow is around 0.086mm/sec, for 1.2mm/sec upflow is around 0.15mm/sec and for 1.6mm/sec upflow is of roughly 0.47mm/sec. While these numbers are significantly different from the previous semester's results (most likely because of our lack of background images), the relationship between 0.6mm/sec and 1.2mm/sec upflow experiments are somewhat similar to the previous semester's results.

1.1 0.6mm/sec

The following graph is a measurement of the height of the floc-water interface of our floc blanket compared to the frame number of the recorded video. The first half of the video appears to have a large range of values, but a trend can still be determined.

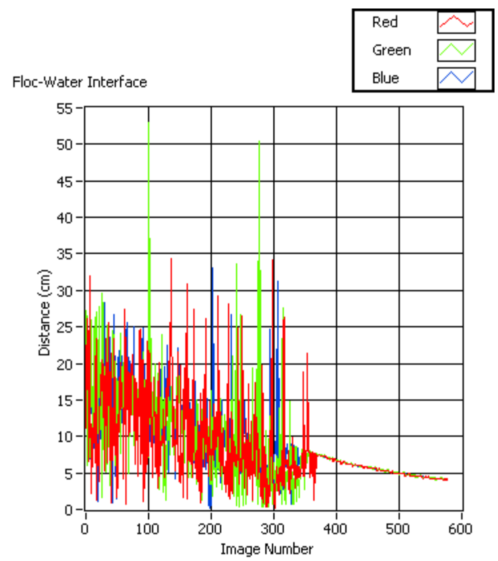


Figure 4: Floc-water interface for 0.6mm/sec upflow velocity

1.2 1.2mm/sec

The data collected from this experiment appears to be the most chaotic. We are hoping that the basic trend of the first 50 images will be accurate enough data to use in our analysis.

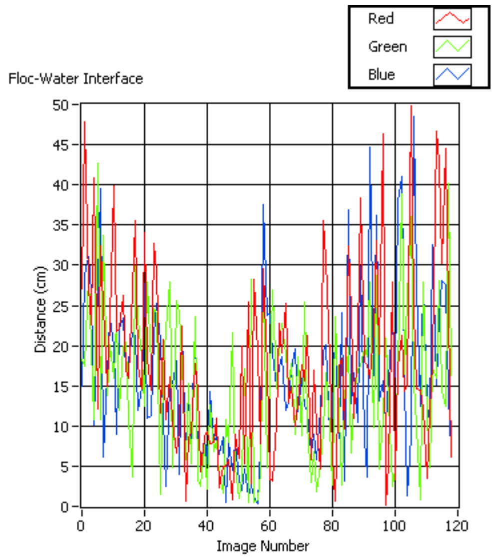


Figure 5: Floc-water interface for 1.2mm/sec upflow velocity

1.3 1.6mm/sec

Similar to the 0.6mm/sec experiment, the first few frames of the video have a wide range of values, but a trend can still be determined. The end of the video has a more consistent trend.

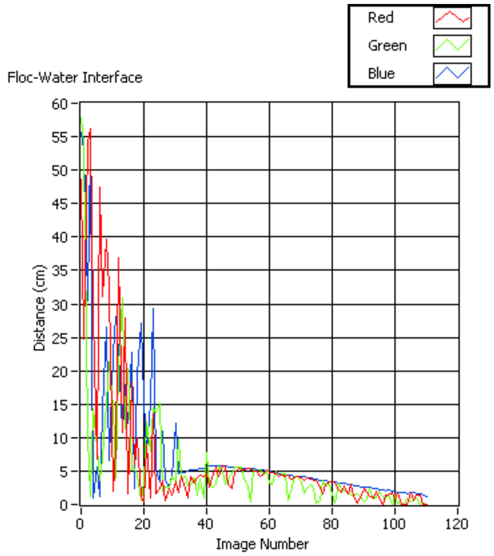


Figure 6: Floc-water interface for 1.6mm/sec upflow velocity

2 Floc Hopper Geometry Experiment

We have discovered that continual wasting will significantly decrease the concentration of flocs in the wier and are currently devising possible experimental designs to increase floc concentration in wiers. Analysis was conducted using the imaging program. Note: Experiments were conducted in the following order, the 15% plan view experiments were conducted first, then 20% plan view, and finally 10% plan view.

2.1 10% Plan View

At the 10% Plan View, we tested three different wasting rates at a 15 mg/L alum dosage. The rates we used were 15ml/min, 25ml/min, and 30ml/min. For the 25ml/min and 30ml/min tests, we attached the barrier strip under the floc hopper in order to keep flocs out of the dead zone. We noticed that for 15ml/min and 25ml/min, the flocs grew to a very high level in a short amount of time and the wasting rate had very little effect in lowering the floc blanket level. The 30ml/min experiment formed a very different floc blanket compared to the two pervious experiments. We are not quite sure why this was so, seeing as we did not change any of the setup before any of the experiments. The floc blanket for the 30ml/min started off slowly, maintaining a height far below the height of the floc hopper. However, after waiting for roughly two hours, the floc blanket rose to the height of the floc hopper and began functioning as theoretically expected. When the weir started wasting, the flocs in the hopper were quickly removed and the height of the floc blanket was maintained, although a lot of clean water was removed by the wasting tube as well. Nevertheless, this result is heartening, as we now know that floc blanket formation will occur, given a long enough time period for the blanket to form. We still are unaware as to why the two pervious wasting rates produced very different floc blanket characteristics. Below are the graphs of the concentrations of the floc blanket in relation to the height of the region of interest for a 10% plan view floc wier. 0 cm signifies the bottom of the floc blanket.

2.1.1 Wasting Rate 15 mL/min

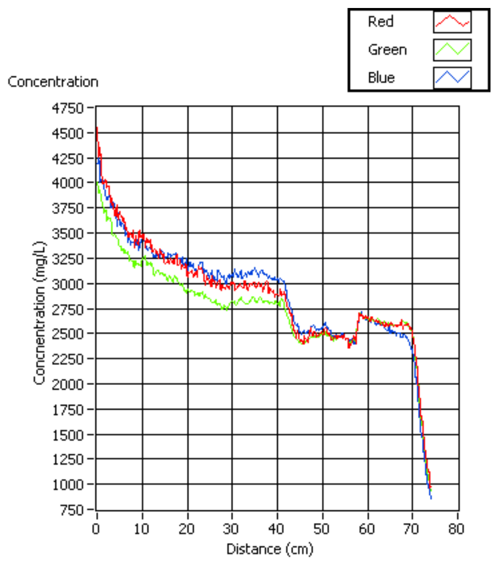


Figure 7: Concentration vs. Height of ROI for 15 mL/min

2.1.2 Wasting Rate 25 mL/min

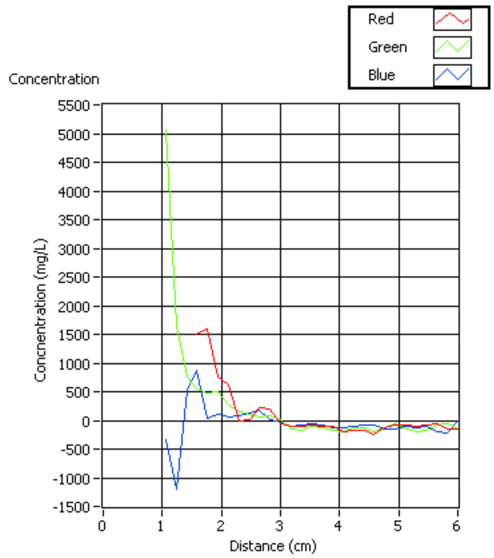


Figure 8: Concentration vs. Height of ROI for 25 mL/min

2.1.3 Wasting Rate 30 mL/min

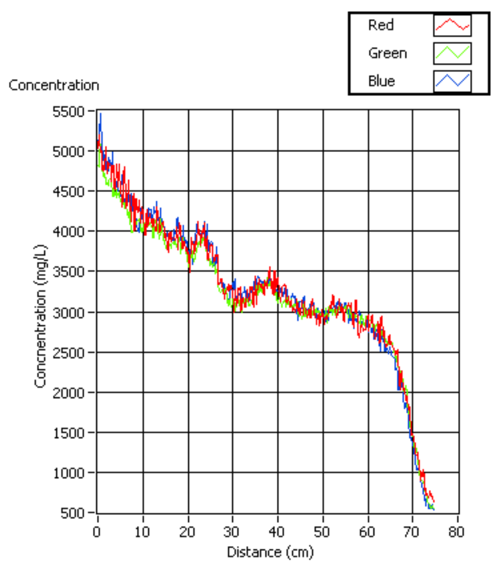


Figure 9: Concentration vs. Height of ROI for 30 mL/min

2.1.4 Analysis

After examining the concentration graphs, we have determined that due to eddies formed in the 25 mL/min experiment, the data from that experiment will be disregarded for our analysis. The height of the floc blanket is represented on the graph by a sharp decrease in concentration on the graphs. In the 15 mL/min experiment, this decrease began at roughtly 70 cm from the bottom of the ROI (Region of Interest: the area that the program studies). In the 30 mL/min experiment, the decrease began around 65 cm from the bottom. This may happen because the wasting rate is higher, and therefore, more flocs are removed from the top of the blanket. The concentration trend for both experiments are similar, with a high concentration near the bottom of the ROI and a slight plateu of concentration at the middle representing the actual floc blanket and then a sharp decline that represents the end of the floc blanket.

2.2 15% Plan View

We have tested the 15% plan view area at three different wasting rates. The rates we used were 15ml/min, 25ml/min, and 30ml/min. This shows a picture of the final floc blanket at these three wasting rates.

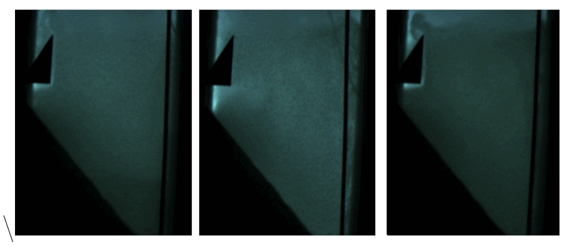
\ 

Figure 10: Floc Blanket Formation (15ml/min, 25ml/min, 30ml/min)

From these pictures10, we concluded that both the 15ml/min and the 25 ml/min wasting rates were not high enough. This conclusion was made based on the fact that the floc blanket takes up the entire sedimentation tank and flows up past the floc weir. For the 30 ml/min wasting rate we can see that the thick floc blanket is maintaining a height very close to the weir height. This shows that this wasting rate is very close to the correct rate. The main concern we have from the 30 ml/min rate is the formation of the eddy at the tip of the weir. We are not sure what implications the eddy formation has on the functioning of the rest of the floc blanket and weir. Below are the graphs of the concentrations of the floc blanket in relation to the height of the region of interest for a 15% plan view floc wier.

2.2.1 Wasting Rate 15 mL/min

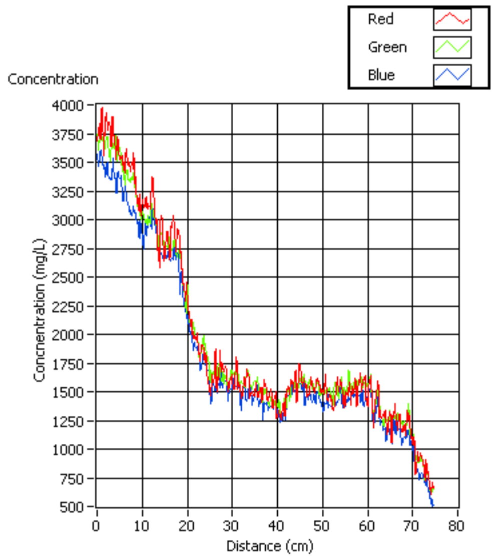


Figure 11: Concentration vs. Height of ROI 15 mL/min

2.2.2 Wasting Rate 25 mL/min

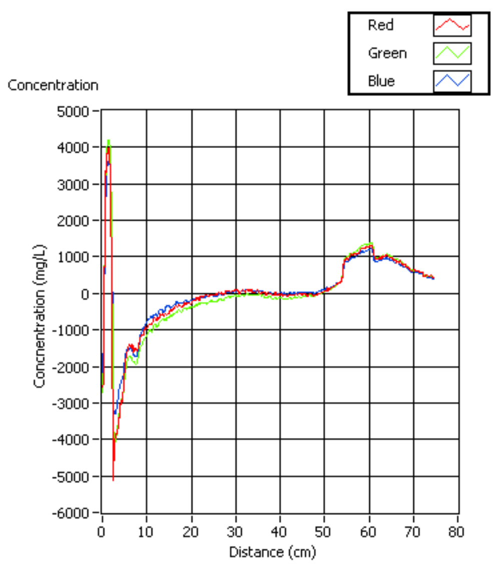


Figure 12: Concentration vs. Height of ROI 25 mL/min

2.2.3 Wasting Rate 30 mL/min

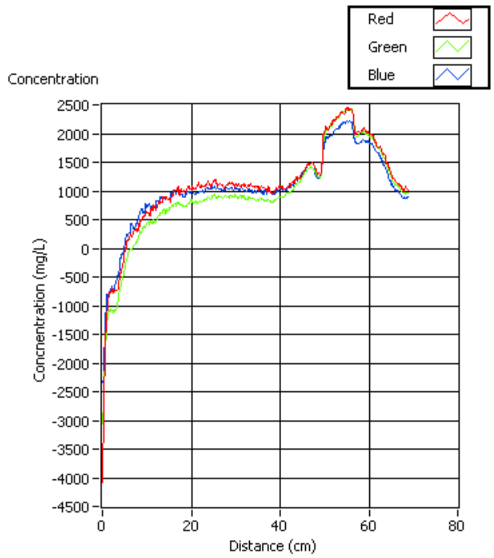


Figure 13: Concetration vs. Height of ROI 30 mL/min

2.2.4 Analysis

For the 15% Plan View experiments, we were running the experiments at a extremely high coagulant dose (45 mg/L) which prevented us from forming a proper floc blanket. A high coagulant dose increases the size of the flocs, but also increases the space in between the glued particles. This space is occupied by water, and therefore makes the larger flocs less dense, and more susceptible to the turbulent water. It is possible that higher wasting rates influenced the overall flow of the flocs which explains why the 15 mL/min experiment has a different concentration profile than the other two experiments. The reason why the 25 mL/min and 20 mL/min concentrations have negative values is because the background image used as reference to the experimental images was darker. Since the analysis program measures concentration by the amount of light showing through the tank, if the experimental image is lighter than the background image, then the concentration is registered as negative. In the future, we will make sure to take background images before every experiment.

2.3 20% Plan View

For 20 percent plan view we have collected data for the 25ml/min wasting rate. The following picture shows the sedimentation tank at the end of the experiment:

Figure 14: 20% Plan View at 25ml/min

This picture (14) shows that floc blanket maintaining a height below the floc weir. We believe that the wasting rate was too high and caused this to happen. The wasting tube can be sucking up flocs from below the weir since this is not fully sealed and some flocs can flow up to the tube through the weir. One of the indications that this could be happening is that the water is significantly lighter right along the left edge of the weir where the wasting tube is.

At the 30 ml/min wasting rate, we changed the alum dosage from 45mg/L to 15mg/L at Monroe's suggestion. We immediately noticed a denser floc blanket as well as smaller flocs. However, we still did not seem to be able to form a floc blanket. Below are the graphs of the concentrations of the floc blanket in relation to the height of the region of interest for a 20% plan view floc wier.

2.3.1 Wasting Rate 15 mL/min

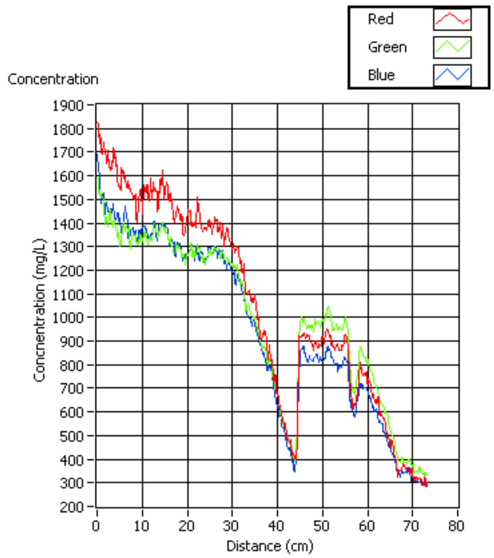


Figure 15: Concentration vs. Height of ROI 15 mL/min

2.3.2 Wasting Rate 25 mL/min

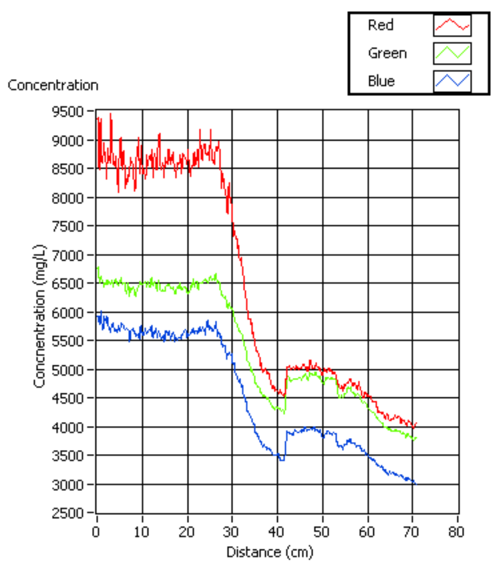


Figure 16: Concentration vs. Height of ROI 25 mL/min

2.3.3 Wasting Rate 30 mL/min

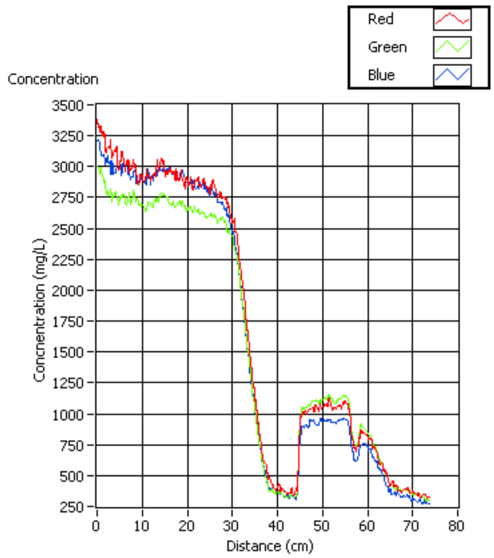


Figure 17: Concetration vs. Height of ROI 30 mL/min

2.3.4 Analysis

For these experiments, we were unable to form a floc blanket, but unlike the 15% plan view, we had a dense concentration of flocs at the bottom of the sedimentation tank. Also, for the first two experiments, the alum dosage was 45 mg/L while the last experiment was conducted with an alum dosage of 15 mg/L. All three concentration profiles have a spike in concentration at around 50 cm from the bottom of the ROI. This could be because of an eddie located on the right hand side of the tank.

3 Constant Wasting Rate

With 1.5ml/min as the wasting rate, the floc hopper remained full which indicates that the floc hopper compressed flocs. However, flocs were more likely to settle down in the wasting tube before reaching the turbidity meter. This explains why the reading of turbidity meter was about 70NTU, a turbidity lower than the influent turbidity. After we figured out that the flocs may be settling down in the wasting tube, we changed the wasting rate from 1.5ml/min to 15ml/min. Flocs settled in the wasting tube were resuspended and the reading of turbidity meter rose to 1100 NTU, the maximum reading range of the turbidity meter. This could indicate floc hopper does compress flocs like expected. At wasting rates of 2.0ml/min and 2.5ml/min, the height of flocs in the floc hopper began to decrease, indicating that the wasting rate was too high to keep the volume of flocs in the floc hopper constant.

Part V
Conclusions

Hindered Velocity Experiment

We have finished compiling all the images recording our three up flow velocity (0.6mm/s, 1.2mm/s, 1.6mm/s) experiments into videos and we have to some extent figured out how to use post-analyze programs to analyze the data. From our data analysis, we are not quite sure about how concentration changes with distance, however, we can conclude that selection of Region of Interest and Background images may cause large variance in the result of analysis. We are expecting the same conclusion as was described in the literature review after we figure out how ROI and Background images affect the analysis.

Floc Hopper Geometry Experiment

We have finished all experiments regarding different plan view area (10%, 15% and 20%) and different wasting rate (15ml/min, 25ml/min and 30ml/min). We also finished compiling all the images we now have into videos. Since it takes us several weeks to get all the experiments done, we changed some of the experiment conditions according to Dr. Weber-Shirk's suggestion and our own new understandings, for example the coagulant dose was changed from 45mg/L to 15mg/L to make the floc blanket denser, the geometry of floc hoppers are also slightly changed. For our most recently done experiment, the plan view area of floc hopper is 10%, with a coagulant dose of 15mg/L and up flow velocity of 1.2mm/s, we could get a floc blanket with the same height of our floc weir about 2 hours after we start the experiment and we could see flocs flowing into the floc hopper from the floc blanket.

Other Findings

1. We have to clean up the turbidity meter each time before we run the experiment, for clay residues settled in the turbidity meter may cause the reading of the turbidity meter to be higher than what it should be, therefore, it could cause the actual inflow NTU to be lower than the reading of turbidity meter which affects the formation of floc blanket.

2. We should clear up the clay residues settled in the tubes and tube conjunctions regularly. Since clay is likely to settle down in the tubes, especially tube conjunctions when we have our apparatus stopped, it may add more head loss to our whole system. Therefore we need to decrease the inflow flow rate and the up flow velocity which inhibits the floc blanket going up.

Constant Wasting Rate

The results of the constant wasting rate experiment suggest that the floc hopper does help make flocs denser but it might be difficult to keep flocs from settling down in the wasting tube when the constant wasting rate is relatively low. Therefore, we may have to wash the wasting tube frequently to prevent flocs settling down in the wasting tube. This experiment suggests that there must be some optimal wasting rate that exists in a range that previous teams have not considered (somewhere between 1.5mL/min and 2.0mL/min).

Part VI

Future Work

1. For the plan view area experiment, it seemed that the smaller plan view areas worked better than the large one. We believe this could also be due to the fact that when we increase the plan view area we are inadvertently increasing the vertical sedimentation velocity. Since increasing the plan view area decreases the space the water has to flow up, the velocity would increase if the flow is kept the same. Therefore the flow into the sedimentation tank should be adjusted so that the upflow velocity is the same for all three plan view areas. Since the variation in vertical sedimentation velocity would be eliminated, the relationship between the plan view areas would be clearer.

2. For our last experiment we used the 10% plan view area. We let a floc blanket form and filled up the floc hopper. We then slowly increased the wasting rate until we maintained a constant height in the floc hopper. This should be done for the other plan view areas. Then they can compare which plan view areas have the most concentrated waste while maintaining a clean effluent.

3. It would be helpful to better understand the relationship between coagulant does and particle size. Halfway through the semester we decreased our coagulant dose and had smaller particles and a more effective floc blanket. It would be interesting to see the difference between particle size and coagulant dose. At some point the coagulant dose will be too low and not remove particles efficiently, but we also suspect that at a high coagulant dose the particles will not form an effective floc blanket. By forming a floc blanket at different coagulant doses, we could find the optimal coagulant dose for maintaining a stable floc blanket and removing the most turbidity. Given enough time this could be run at various influent turbidity.

4. Understanding floc blanket failure modes would be helpful to plan operators. The relationship between coagulant does and floc blanket failure

could be found from the previous experiments. With this information we should write a manual to help plant operators understand what is causing their floc blanket to fail and how to remedy it. It would also be interesting to see if the influent turbidity will also cause floc blanket failure. From the conclusions of the future semester's work a guide for the plant operators can be written.