AguaClara: Flocculator Efficiency

Fall 2015

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Abstract

The Fall 2015 Flocculator Efficiency subteam worked on designing, developing, and testing a flocculator model that optimizes the vertical-flow flocculator used in AguaClara water treatment plants. The team addressed the accumulation of low-shear regions of water above the top of the lower flocculator baffles, a phenomenon that creates a “dead” region in which collision potential for the creation of flocs is very low. Dead zone formation occurs due to a decrease in fluid velocity as water transitions from the bottom of the flocculator to the top and as it flows over the lower baffles. The team hypothesized that compressing the water flow would increase the fluid velocity and, as a result, allow the water to flow at a higher trajectory over the lower baffles and reduce the formation of dead spaces. Furthermore, the addition of an extra contraction and expansion would create more turbulence in the region above the lower baffle and increase collision potential. This issue was addressed by installing obstacles in the form of slit pipes at the tops of the lower baffles. Test results with these features showed that the obstacles were able to compress the flow and consequently increase the fluid velocity and turbulence in the ‘dead zone’ region. The team measured and observed the results of this design feature by testing the model through flow visualizations using a red dye tracer. Among the variables tested, the best desired effect was observed with a restriction of 78% of channel width, for both laminar flow and potentially turbulent flow (Re= 3000). With a 60% restriction, the formation of a circulating region was observed, although this eventually cleared up. There is a need for further research on how the geometry of the obstacle might be impacting this phenomenon.

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Introduction

The flocculator is the component of the AguaClara water treatment plant design in which suspended particles coated in coagulant are allowed to group together and form larger flocs. These flocs can be removed from the water through sedimentation and filtration, carrying away unwanted contaminants with them. It is desired that flocs are big enough to settle and be removed in the sedimentation tank, but small enough that they do not settle directly in the flocculator or stop combining with other particles. AguaClara plants use vertical flow flocculators to conserve space, meaning that the baffles are held vertically and water flows over and under them (*Figure 1*).

A problem that has been observed with this design is that the upward velocity of the water decreases as it rises over the lower baffles, causing the fluid to flow immediately over the lower baffle and leaving an unutilized dead zone of low shear circulating fluid (*Figure 2*). Collision potential for floc formation in this zone is low. The main goals of the Flocculator Efficiency subteam are to minimize this dead zone by increasing the upward velocity of the water as it flows over the lower baffles, and by increasing turbulence in the region above the lower baffles.

This problem is being addressed in the full-size plants through the introduction of obstacles to compress the flow and increase its upward velocity, but the results have not been satisfactory with solely two obstacles per baffle. The plan for further improving the design is to introduce additional obstacles to compress the flow by 60% or more at a point near the tops of the lower baffles (*Figure 2*). Fluid that is more compressed will have higher velocity and therefore will be able to rise up higher into the dead-spaces. Moreover, the additional compression and following expansion will allow for greater turbulence. However, one constraint is that water should not shoot out from the surface and run over the top of the upper baffles.

In order to formulate a solution for the dead zone problem, the team first had to recreate and demonstrate the formation of dead zones in a small scale model flocculator. Once the team was able to clearly demonstrate the problem using a red dye for a flow visualization in the model, obstacles in the form of slit plastic tubing (*Figure 4*) were added to the tops of the baffles to observe the effect on partial or full elimination of dead zones. Since the tubing used was flexible, individual obstacles could be compressed to different extents, which allowed the team to test for different restriction sizes. Effects were also studied for two different water levels to represent the change in head-loss between different flocculator channels, as well as for laminar and potentially turbulent flow. Based on the results of this assessment, future studies might attempt to optimize the size and geometry of obstacles in proportion to distance between baffles in order to make the most efficient use of flocculator space.

This information will allow AguaClara plants to utilize space more efficiently, and thus maximize collision potential for floc formation. Maximizing floc formation will allow for better reduction of turbidity in the sedimentation and filtration stages of the treatment, while minimizing the number of obstacles/ material used in the plant will contribute to reduction of cost and retainment of simplicity.

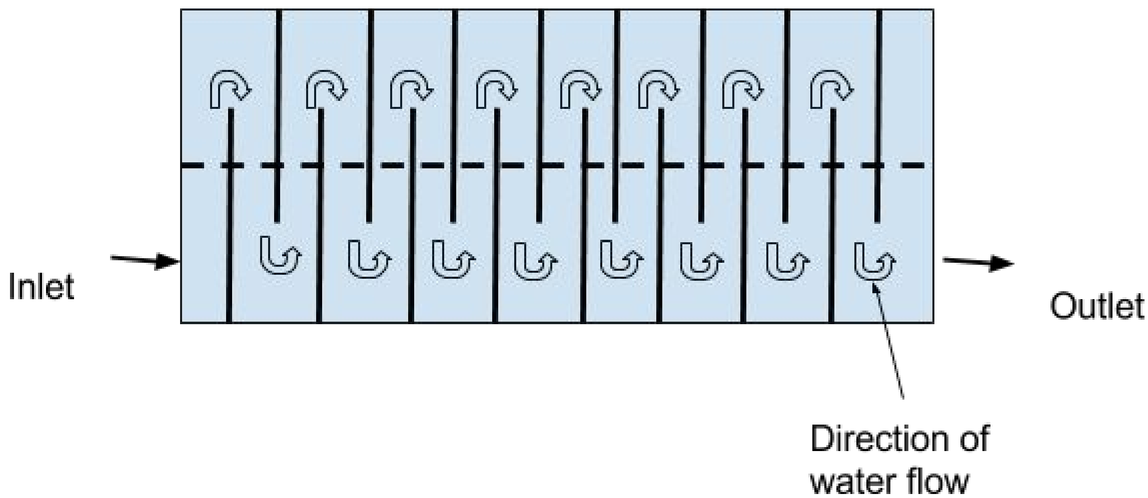

Figure 1: Basic flocculator design with direction of flow indicated around each baffle.

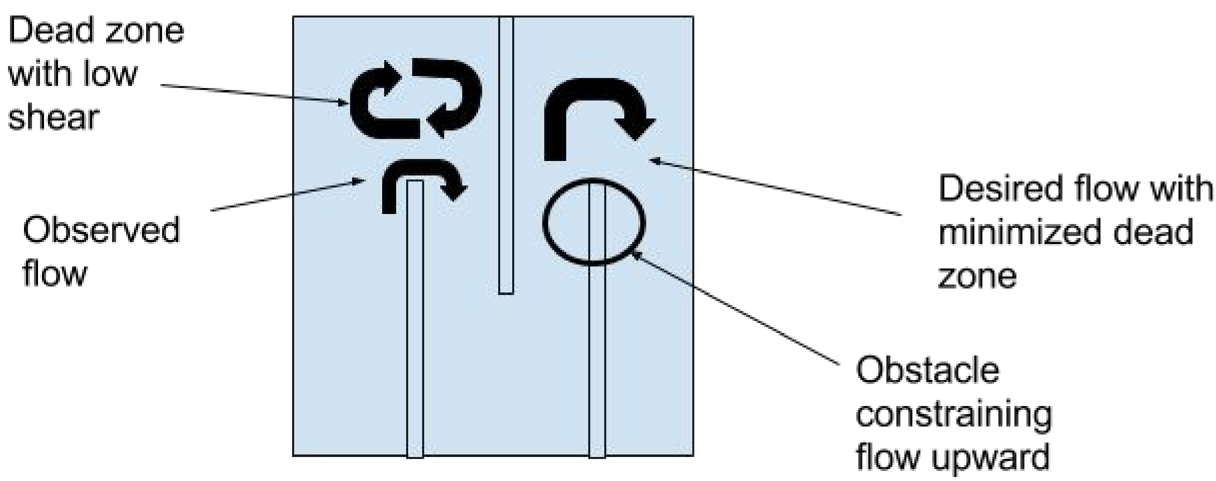

Figure 2: Observed problem of low upward velocity above lower baffle accompanied by dead zone of low shear (i.e. low collision potential), and desired flow with minimized dead zone and high collision potential due to addition of obstacle.

Literature Review

To determine efficiency bottlenecks in the current flocculator design, the Flocculator Efficiency Team consulted slides from CEE 4540 (a class on sustainable, small-scale water supplies offered at Cornell University) to understand the function and operation of the flocculator chamber [1]. In addition, the team studied key fluid mechanics concepts using notes from

Cornell's course CEE 3310 [2]. In the flocculator, water flowing around the edge of baffles expands as it changes direction. This creates turbulence that forces particles to collide and stick together, creating growing flocs that can be sedimented out of the water. Water closer to the baffles experiences a sharp change in flow direction, while water further away from the "turn" alters direction less dramatically and over longer length and time scales. The result is that water further from the turn experiences less turbulence as its flow gradually changes. In addition, this water shoots up further over the baffles and pinches off into eddies that do not fully travel around the baffle's end, but instead remain above the baffles without mixing. These non-turbulent eddies constitute dead-spaces that diminish the flocculator efficiency, because they take up volume in the tank without contributing to the mixing. Literature review has confirmed that this phenomenon is a bottleneck that must be addressed to enhance efficiency, and has informed and shaped the approaches the team is implementing to create an optimized flocculator.

In order to calculate maximum energy dissipation due to a single obstacle, the team used concepts and equations from the CEE 4540 notes.

Methods

Overview

A small-scale model flocculator was constructed to illustrate the existence of dead zones and test the effectiveness of the adding the obstacles to the flocculator. A three-dimensional plan for the model was drawn using the software SketchUp (*Figure 8*). Once the model was constructed, preliminary trials were conducted with no additional obstacles (only placeholders), to observe the flow visualization from addition of dye. Problems were identified and addressed, and the experiment was carried out with obstacles for a laminar flow (Re< 2000), and a potentially turbulent flow (Re~ 3000)

An acrylic glass box with an open top was used as the flocculation tank, and strips of acrylic were cut using a table saw and and served as the baffles. Wire was used to suspend the baffles in place within the open-top box. The baffles were strung onto three wires (*Figure 9*) using holes that were drilled in machine shop. The obstacles were made using rigid tubing to serve as half pipes (*Figure 4*), and were attached to the baffles at locations indicated in *Figure 2*. An influent peristaltic pump was used to set a flow rate in order to best simulate how the flocculator performs in realistic flow conditions (see *Dimensions and Constants*). The pump was connected to the flocculator model using rubber tubing and connectors. Injection of red dye using a pipette helped create a flow visualisation. If necessary for future teams, a sedimentation tube might be installed, and influent and effluent turbidity of a clay solution will be observed to quantify results.

The flow made visible due to the instantaneous injection of dye was captured at different instants of time through video recordings taken using a camera. This allowed the team to understand what path the fluid follows as it flows over the lower baffles. The presence of dead zones was demonstrated by the presence clear regions, which later turned to regions of low-shear, circulating dyed fluid above the lower baffles while the rest of the dye was cycled through the entire the flocculator such that clear water eventually replaced it. The reduction of such circulating zones would indicate the attenuation of dead zones. The team hypothesized that the visual difference in the path from introducing additional obstacles would be dramatic enough to observe qualitatively. Future quantitative measurements will be even more precise, and might involve measuring influent vs. effluent turbidity, as described previously.

Once the formation of dead zones was properly demonstrated in the model, slit acrylic tubing was used to make obstacles to restrict the upward flow by different percentages at it approached the top of the lower baffles. The restriction size was manipulated by compressing the slit flexible tubing to different extents and measuring the horizontal thickness (*Figure 3*).

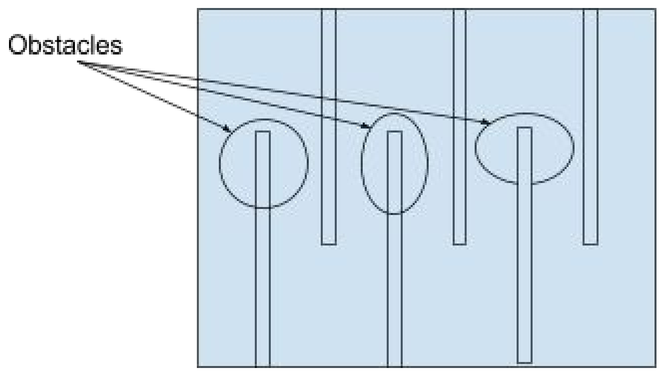

Figure 3: Different restriction sizes facilitated by compressing the flexible tubing to different extents.

The two main goals with addition of obstacles were:

1. To fully utilize the space above the lower baffle, i.e. to have fluid flow through the entire space instead of just below the dead zone.
2. To increase turbulence in the region above the lower baffles through addition of an extra contraction and expansion, which in turn increases collision potential.

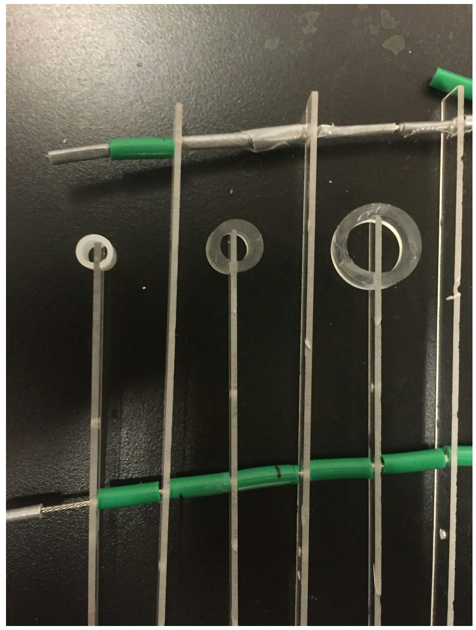

Figure 4: Different sizes of obstacles considered for use in the experiment. The tubing third from right was the only kind used in the experiment.

Construction

Shell:

A pre-made acrylic box was used as the flocculator shell, which represents a single channel of the flocculator in the full size plant (see *Dimensions and Constants* for specific dimensions). The box has a much smaller width in proportion to length and height than the full-size plant, but this was assumed to have a negligible effect on the upward velocity of the water as it flows over the lower baffle. It was assumed that in a wider model, the same pattern could be projected out in the dimension of the width. The box was cleaned using narrow brushes and water to allow for easy observation of the fluid flow.

The team tested the box for leakages by running water through it and found that the sides and base were not water-tight. Thus, the base and sides were coated with PVC glue and left to dry for several hours. A subsequent test for leakages showed that the shell was still not successfully made watertight, as PVC glue is not suitable for adhering acrylic together. The shell was sanded to remove the PVC, and acrylic glue was injected into the exposed cracks using a syringe (*Figure 5)*. There were thus no more significant leaks from the shell.

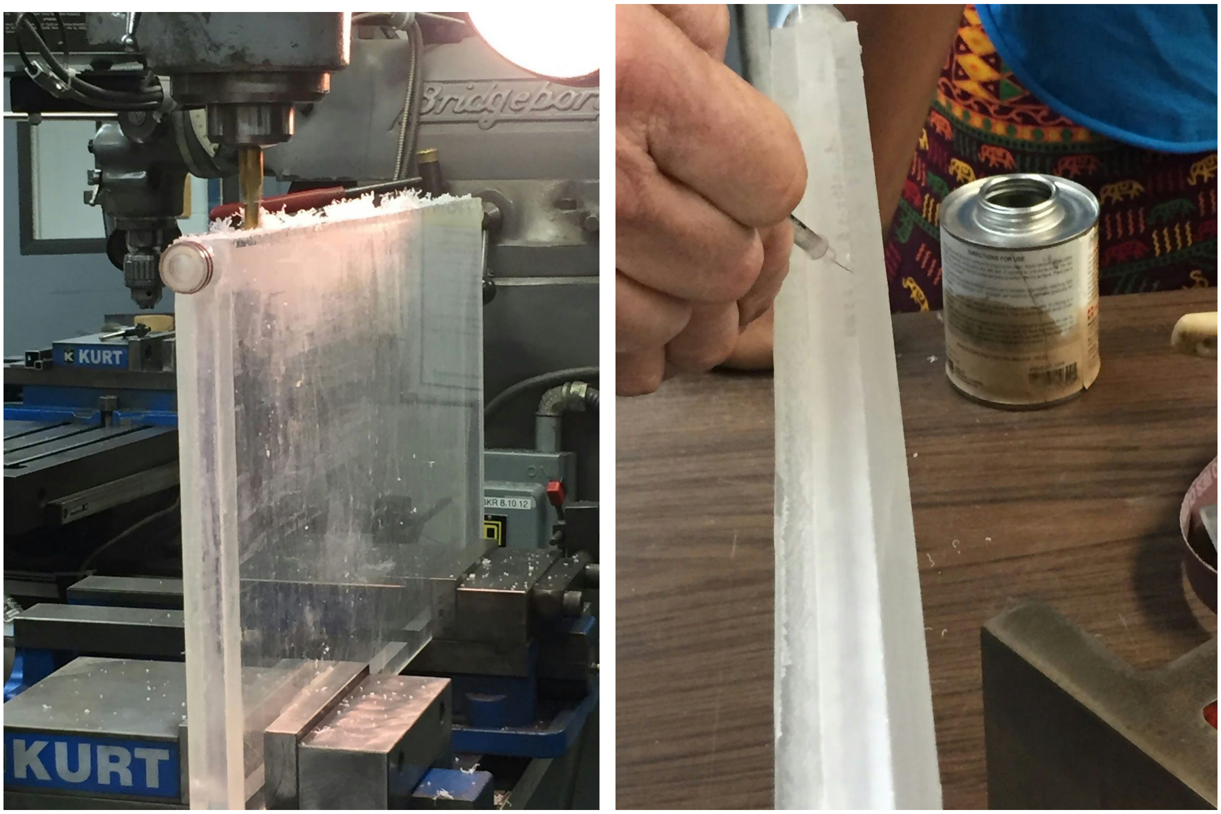

Figure 5: Left: Removing PVC glue from the flocculator shell. Right: Injecting acrylic glue between the cracks with a syringe.

Pumps:

Water was set up to flow into and out of the flocculator through ⅜ in clear flexible tubing and size 18 (8 mm) peristaltic pump tubing. The appropriate connectors were used around the peristaltic pump and into and out of the flocculator shell. A 100 rpm was used for the laminar flow, while a 600 rpm pump was used to produce the potentially turbulent flow with Reynold number ~ 3000.

Baffles:

The original plan was to use sheets of acrylic for the baffles and cut them individually to the required baffle size. However, it was observed that cutting the baffles in the machine shop gave very rough edges that the team believed would create small gaps between the walls and the baffles, allowing water to flow in between. To avoid this issue, water-resistant nylon strips of 1.25 cm width (½ in) and ~0.2 mm thickness were procured for the baffles, which were cut only to the required length. On attempting to insert the baffles, it was found that the acrylic shell had a non-uniform inner thickness, meaning that strips of exactly 1.25 cm width would not fit in all parts of the shell.

Since the full-scale plant itself *does* have gaps between the baffles and the inner walls of the flocculator, it was decided that the acrylic baffles would be cut to a 1.1 cm width, which would allow them to fit in the narrowest part of the shell, while leaving small gaps at other places. This was deemed to not affect overall fluid flow significantly, so the team proceeded with this modified setup.

The baffles were cut using a table saw in the machine shop to the dimensions specified under *Dimensions and Constants*. A hole was then drilled in each baffle at 0.5 cm and 12.5 cm along the central axis down the length using the drill at machine shop.

Assembly (Wires and Placeholders):

Three wires of approximately 0.2 cm in thickness were threaded through the baffles as illustrated in *Figure 9*. In order to hold the baffles in place and maintain a constant distance between them, pieces of rigid tubing with specific lengths were threaded in between the baffles like beads on a necklace (1.7 cm for middle wire, 3.4 + 0.1 cm for the upper and lower wire). The ends were sealed with putty and stuck to the end walls of the flocculator (*Figure 6*). The putty was later replaced by pieces of duct tape which offered greater stability.

This design allowed the team to vary the distance between baffles, and to change the size and number of baffles relatively easily. The entire baffle-wire setup (including 3 wires, 2 rows of baffles, plastic separator tubing, and putty) was then lowered into the flocculator shell.

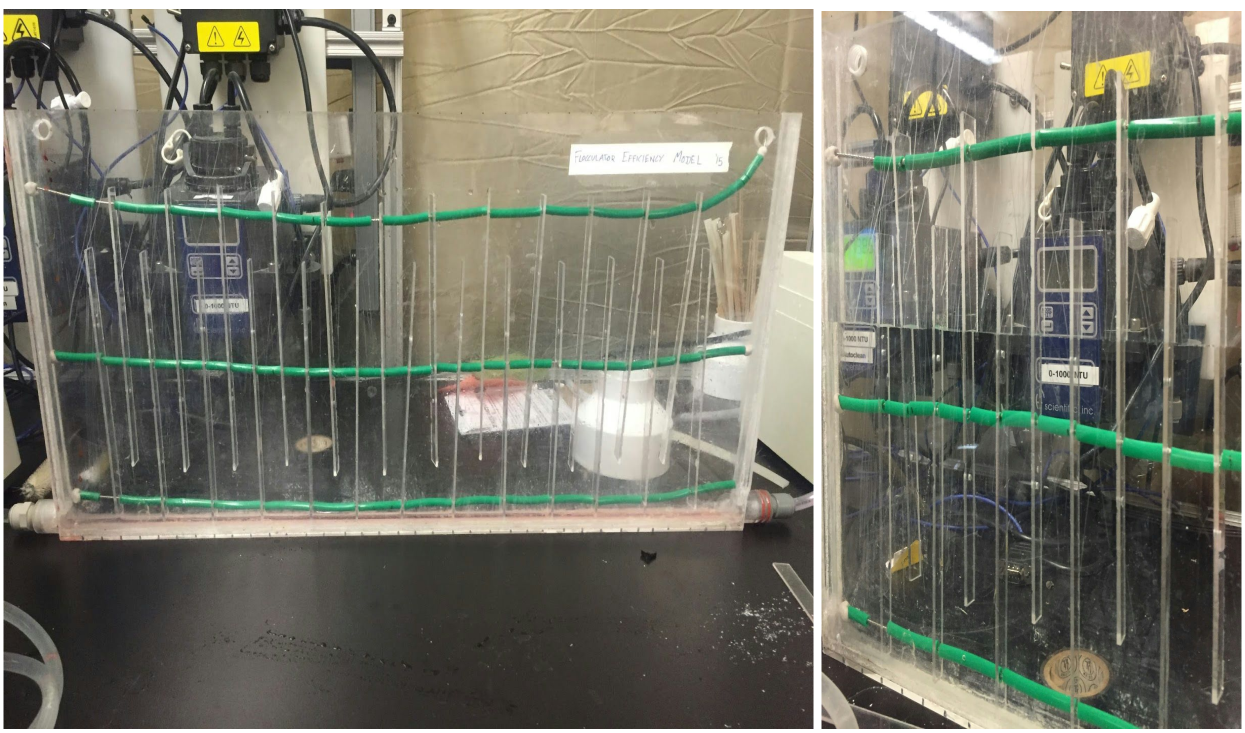

Figure 6: Left: Model flocculator with no obstacles and thicke rplaceholders. Right: Assembly of the baffles with wires and placeholders.

However, compared to the width of the flocculator shell, the green tubing initially used for placeholders had a very large thickness. As a result, it was creating a significant compression to the flow, increasing the flow velocity and providing an inaccurate representation of the phenomenon without obstacles in the full-scale plant. The team decided to instead use thinner placeholders with the same length as the green placeholders, as shown in *Figure 7*. The new placeholders were did, in fact, allow the team to more clearly visualize dead regions than the previous placeholders.

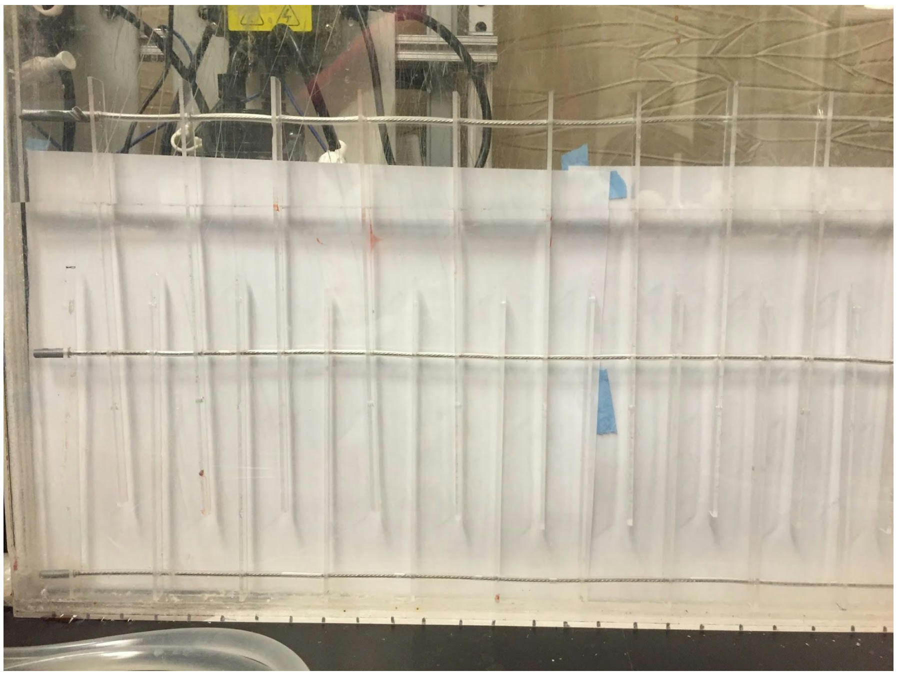

Figure 7: Model flocculator with the newly replaced (thinner) placeholders.

Flow Rate

The team was studying the efficiency of the flocculator in periods of low flow, i.e. an approximate value of 10 L/s in the full-size plant. The small scale model constructed by the team represent one channel of the flocculator in the plant, and the dimensions of one channel are as follows:

Height: 2.08 m

Width: 0.53 m

Length: 4.33 m

Volume: 4.77 m^3

The volume of the team model is 2.2E-3 m^3 (see *Dimensions and Constants* for dimensions). Thus, the model flow rate for the initial experiment was found by dividing the plant flow rate by the plant volume and multiplying by the model volume. This yielded a value of 4.6E-3 L/s. The peristaltic pump was thus suitably calibrated to an rpm of 57.3 and peristaltic pump tubing size 18, which gave the team a flow 260 mL/min m or 4.3 ml/s. The calibration was done by hand, using the chart from the AguaClara wiki as a guide, around which adjustments were made for the team's specific set-up [3].

It was then found that this value of flow rate yielded a laminar flow, while the full scale plant always experiences a turbulent flow. In order to recreate the situation realistically, the model flocculator would also have to have a turbulent flow. The team attempted tests for both laminar and turbulent flow.

To calculate a new turbulent flow rate, the minimum Reynolds number for the flow was set to 4000. The characteristic length, i.e hydraulic diameter, was calculated for a rectangular duct considering the rectangular cross section of the space between two baffles (1.3 cm x 1.7 cm), using the following equation:

$$d_h = \frac{2ab}{a+b}$$

where d_h represents the hydraulic diameter, and a and b represent the sides of the rectangular duct.

Once this value was obtained, the Reynolds number was set to 4000 and the following equation was used to solve for v (velocity of water through the channels between baffles):

$$Re = \frac{\rho u L}{\mu}$$

where Re represents the Reynolds number (4000 in this case), ρ as the density of water, u as the velocity along the 'rectangular ducts' between baffles, L as the hydraulic diameter, and μ as the dynamic viscosity of water at room temperature. The value v was multiplied by the cross sectional area of each channel to provide a flow rate. This gave a value of 5.1E-5 m^3/s, or 51 mL/s.

To achieve a higher flow rate, the 100 rpm pumps were replaced by 600 rpm pumps. These pumps could still not achieve a flow rate of this magnitude, thus they were set to their maximum value to achieve as close a value as possible. This yielded a flow rate of 38 mL/s. The Reynolds number for this value is ~3000, which is potentially turbulent. Visual observations of multiple small eddies within the rectangular duct region lead the team to believe that the flow is most likely turbulent.

Calculations were made using MathCad.

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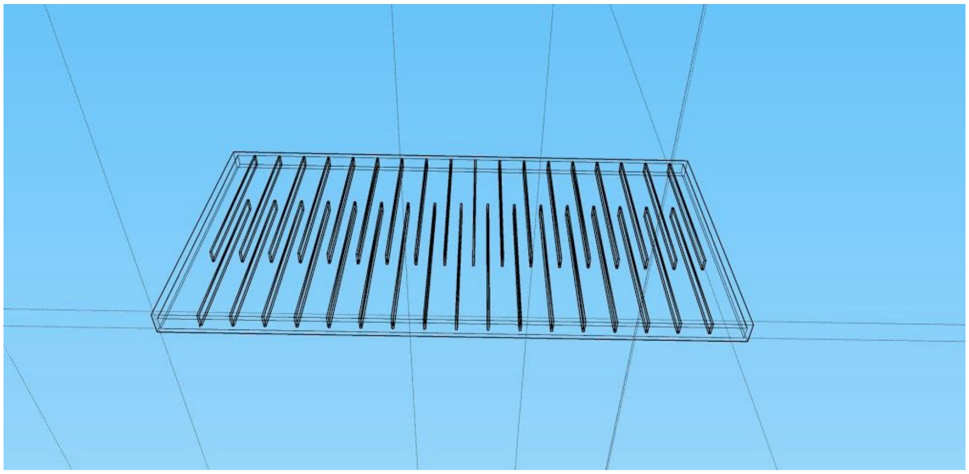

Figure 8: Three-dimensional view of flocculator model lying on its side (wires and obstacles not pictured).

Troubleshooting

On conducting preliminary trials with this design, the following problems were encountered and dealt with as described below:

1. There was a buildup of red dye between the initial baffles due to leaks at the bottom of some of the lower baffles. This was first combated by adding pieces of putty to the bottoms of the baffles where leaks were particularly problematic. Later, the baffles were rearranged so that there were minimal leakages amongst the first few baffles, which were most significant to the experiment because they provided the clearest flow visualization. As a result, the water flowed as desired, and there was no longer a buildup of red dye between the baffles.
2. The gaps between the baffles and the shell, while structurally acceptable, created problems with the flow visualization since a lot of dye could flow through this space, making it difficult to observe the main trajectory. This was combated using a metal clamp to hold tight the middle of the shell (which is the part that expands more easily). This allowed for a clearer flow visualization of the main path of fluid in the model. Later in the experiment, two more clamps were added for additional tightness.
3. The height difference between the tops of the lower baffles and the tops of upper baffles was insufficient to illustrate the dead zones as they are observed in the full-scale plant. Based on the design obtained using the AguaClara design tool, the ratio of this height difference to the horizontal distance between each baffle, s, should be 5.0. Since the value of s in the model is 1.7 cm, the value of the height difference was calculated to be (5.0×1.7) cm, i.e. 8.5 cm. In order to implement this new height difference value while retaining the positions of the wires and the overlap between baffles, the lower baffles were cut to a new length of 16.5 cm, from the old length of 20.0 cm. Thus, there are now two different baffle lengths for lower and upper baffles.

4. The addition of dye using a pouring method did not clearly demonstrate the flow of water since ideally dye would be injected at a lower point in the flocculator. This problem was addressed with the use of a pipette for dye injection in following trials.
5. The 100 rpm peristaltic pumps could achieve a flow rate that created a turbulent flow. Thus, they were temporarily replaced with 600 rpm pumps, which came close to achieving the required flow (a Reynolds number of 3000 was obtained).

Dimensions and Constants

The dimensions and relevant constants for the various components of the model flocculator for the first trial are listed below. These dimensions have been determined using the data provided by the AguaClara web-based design tool. Since the data given by the design tool were based on the actual flocculator, the team used dimensional analysis and proportionality ratios to arrive at the correct numbers for the scale model:

Tank

- Inner width: 1.3 cm
- Inner height: 29.0 cm
- Inner length: 59.0 cm
- Wall width: 0.5 cm

Baffles

- Number of baffles: 29: The original value of 35 was selected based on baffle number to flocculator length ratio from the dimension obtained through 'Design Tools' on the AguaClara website. The team is using only the baffles immediately after point of injection of dye to make observations since the flow visualization is clearest here, thus baffle number is not significant to this experiment
- Thickness: ~0.1 cm
- Width: 1.1 cm : Height and width are selected to fit perfectly with the narrowest part of the interior of the shell)
- Upper baffle length: 20 cm
- Lower baffle length: 16.5 cm : This difference in baffle height allows the model to conserve the ratio of overhead space to horizontal distance between baffles. The value 5s represents the distance in which a compressed flow will undergo full expansion.
- Length of vertical overlap: 12 cm
- Horizontal distance between baffles: 1.7 cm
- Overhead space, i.e. vertical distance between top of lower baffle and top of upper baffle when both are mounted on respective wires: 8.5 cm : This value was obtained using the ratio of horizontal distance between baffles and overhead space from the design tool, which is 5.0

Wires

- Thickness: ~0.1 cm

- Length: 59 cm (to fit inside shell)

Obstacles (slit tubing placed at top of lower baffles)

- Diameter: 1.1 cm (60% of the horizontal distance between baffles)
- Width: 1.3 cm (to fit perfectly in box)

Pump

- Tubing size: #18 (8 mm)

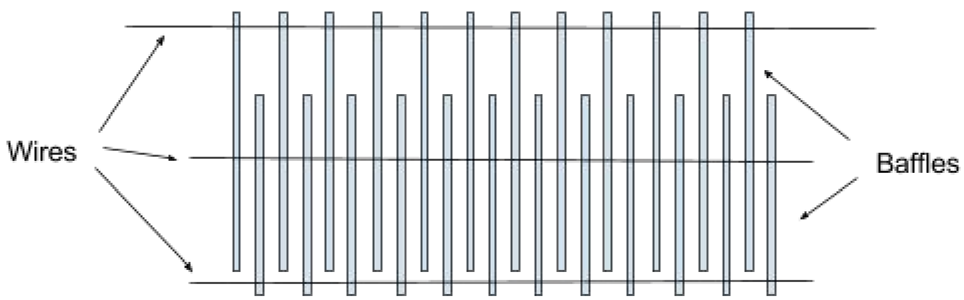

Figure 9: Side view of the baffles strung on wire displaying height differences. The wires go through holes made down the central line of each baffle.

Figure 10: Left: Inserting red dye into the model. Right: Observing fluid flow with the red dye.

Results and Analysis

PRELIMINARY TRIALS

With the set-up in place, the team ran preliminary trials with flow visualization to make qualitative observations about the flow pattern without obstacles installed. Tests revealed several issues:

- Gaps between the baffles and outer shell allowed a substantial amount of water to pass through. This did not correctly reflect the vertical flow that should occur.
- The height above the lower baffles was restrictively small, allowing for little variation in water height through the flocculator.
- The upper baffle did not extend close enough to the base of the flocculator shell. Fluid flow was thus inadequately constrained to curve around the bottom of the upper baffles. Overall, this produced a wasted region similar to the dead space we wanted to simulate above the lower baffles..
- The lower baffles were not tightly grounded to the floor of the flocculator shell. This allowed water and dye to slip underneath the lower baffles and flow horizontally instead of vertically.

These issues were dealt with in subsequent improvements to the physical model, as described in *Methods: Assembly*. The resulting system was more robust, and in later trials, dead zones with low shear and circulating dye were clearly observed as intended.

PRIMARY TRIALS

The overall experiment comprised of trials and control experiments. Both laminar and turbulent flow were investigated with obstacles attached to the baffles, and the results compared to trials without obstacles.

Obstacles were fabricated using slit flexible tubing. The tubing was cut into short cylinders that straddled alternating baffles and matched the baffle width. Since the tubing was compressible, the team could dynamically alter the extent to which the obstacles restricted vertical water flow. For trials with high Reynolds number, turbulence was confirmed when the dye injected into the flow stream demonstrated high local variation in speed and direction.

The tables below summarize experimental results from trials where the effective channel width was varied by altering the obstacle size.

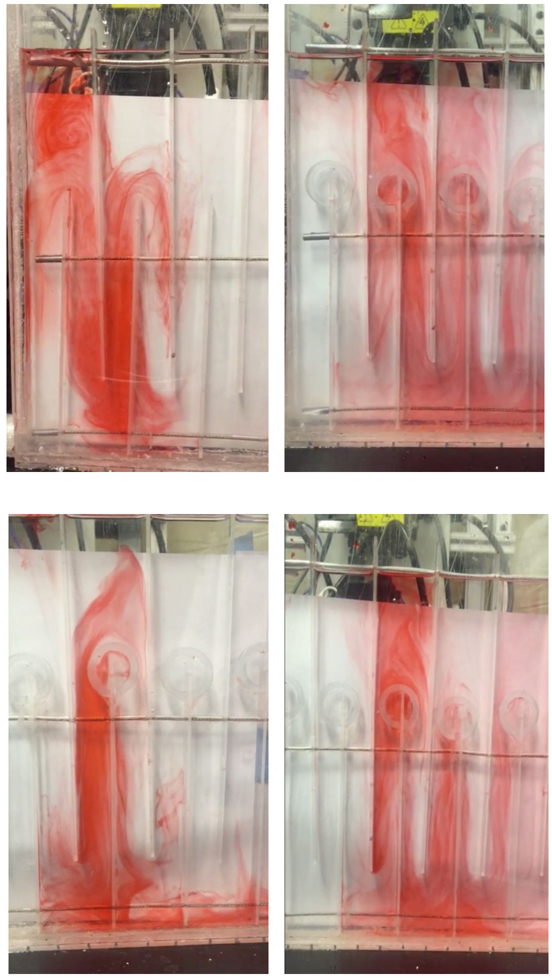

Figure 11: Laminar flow visualization with a red dye. The channel width, from top left going clockwise: 1.7cm (No obstacle), 0.1cm, 0.3cm, 0.8cm.

Laminar Flow:

Table 1: Observations for Laminar Flow

Channel Width	Observations
1.7 cm (No obstacle)	Dead zone: only partial utilization of space, circulating region, apparent low turbulence.
0.1 cm	Full utilization of space, no circulation, apparent high turbulence
0.3 cm	Full utilization, no circulation, apparent high turbulence
0.7 cm	Some circulation, not ideal utilization of space, apparent high turbulence

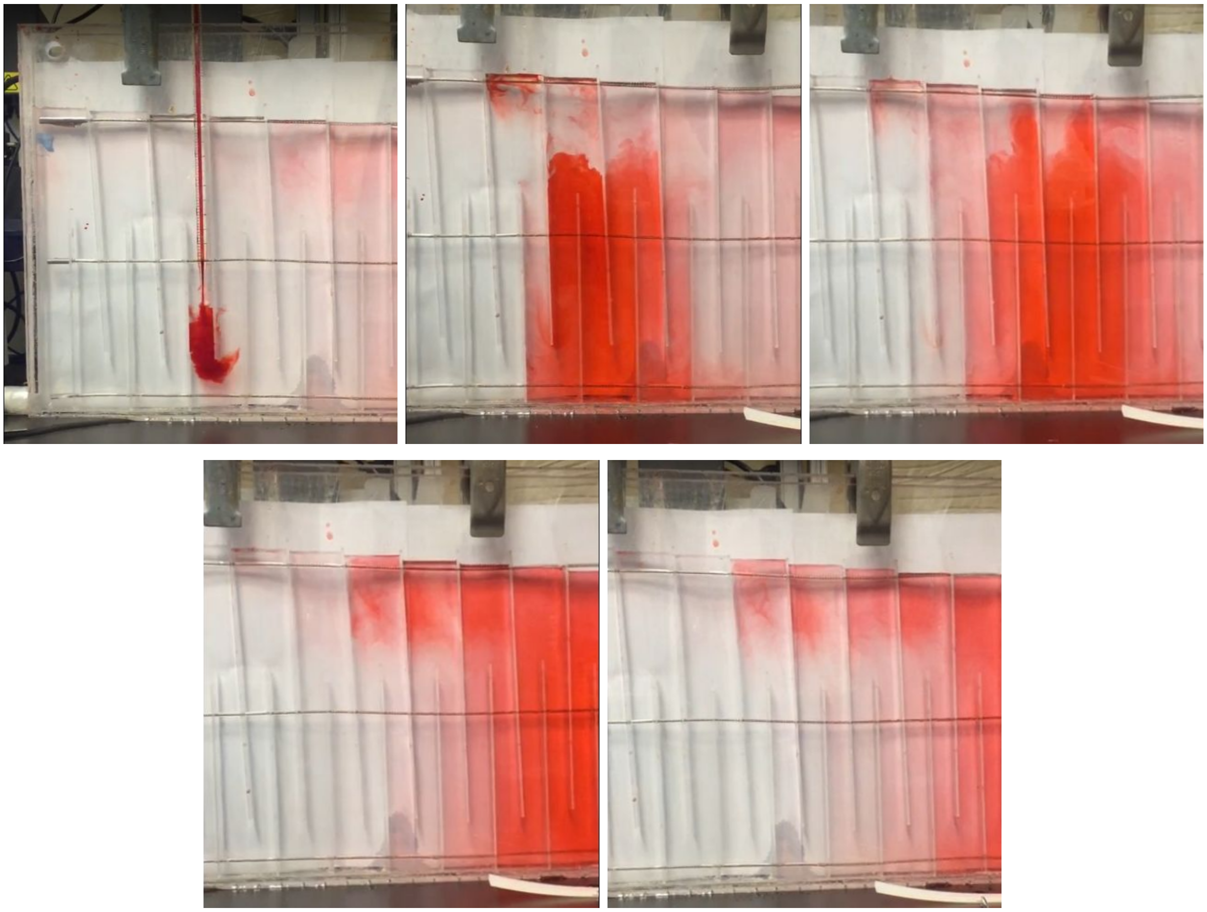

Figure 12: Turbulent flow visualized with red dye. No obstacles were included here, resulting in dead spaces with a relatively low rate of fluid passing through.

Turbulent Flow:

Table 2: Observations for Turbulent Flow, Full Depth

Channel Width	Observations
1.7 cm (No obstacle)	Dead zone: only partial utilization of space, circulating region Turbulence appears to be stratified: fewer eddies in dead zone
0.1 cm	Full utilization of space, no circulation, apparent high turbulence
0.3 cm	Full utilization of space, no circulation, apparent high turbulence
0.7 cm	Some circulation (smaller than same case, laminar flow), apparent high turbulence.

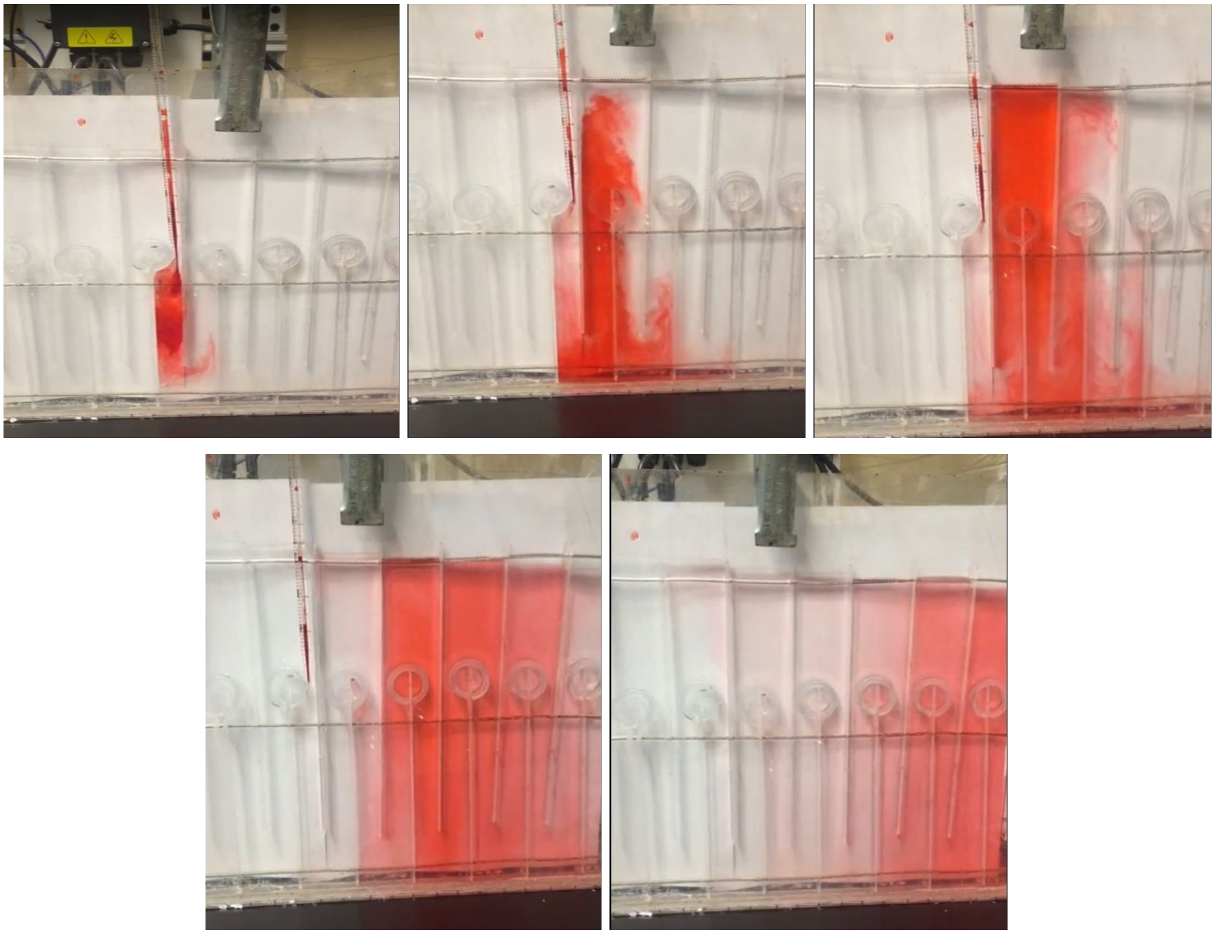

Figure 13: Turbulent flow visualized with red dye. With obstacles included, dead zones were dramatically reduced.

Table 3: Observations for Turbulent Flow, Partial depth

Channel Width and Obstacle	Observations
1.7 cm (No obstacle)	Full utilization of space, no circulation, apparent high turbulence
0.1 cm	Full utilization of space, no circulation, apparent high turbulence
0.3 cm	Full utilization of space, no circulation, apparent high turbulence
0.7 cm	Full utilization of space, no circulation, apparent high turbulence

The maximum energy dissipation for a single obstacle was calculated based on the following equation:

$$\varepsilon_{max} = \frac{(\Pi_{jet} * V_{jet})^3}{S_{jet}}$$

Where Π jet= 0.225, approximating to a 2-dimensional flow, Vjet is the velocity of the jet, and Sjet is the width of the channel between baffles or between obstacles and baffles.

Table 4: Maximum energy dissipation for various restriction sizes

Channel Width	ε_{max}
1.7 cm (no obstacles)	5.7E1 J
0.1 cm	4.8E6 J
0.3 cm	5.9E4 J
0.7 cm	1.9E3 J

Thus, greater constriction is associated with a significantly higher energy dissipation. This contributes to increased turbulence, which a desired effect. The higher turbulence additionally serves to limit floc size, so that they are less likely to settle in the flocculator itself, and more likely to combine with other free particles.

Analysis:

From these observations, the team was able to see that the original hypothesis was correct. As shown in *Figure 11*, the introduction of obstacles above the lower baffles reduced dead zones considerably. Additionally, the team was also able to make a correlation between the channel width (the distance between the baffle on the left and the obstacle on the right) and the amount of utilized space above the lower baffle. Again, looking at *Figure 11*, the team was able to conclude that the narrower the channel width the better the utilization of space and thus less regions of dead zones.

The high effectiveness of the obstacles that created 0.1 and 0.3 cm channels (i.e. minimum of ~ 78% restriction) at eliminating the formation of dead zones might suggest that single obstacles at the top of each lower baffle would be sufficient to address the dead zone problem in the full size plant. The obstacle currently in place at the sides of the lower baffles might no longer be necessary with the addition of these baffle-top obstacles, as long as they create a large enough restriction in channel width. The use of a single slit pipe instead of multiple obstacles would also help retain simplicity in the plant design and reduce the quantity of material required.

There is a need for further research on the effects of these baffle-top obstacles in a wider channel, with a higher flow rate, to get a better understanding of their ability to eliminate dead zones in a full size plant. Furthermore, the ideal obstacle size, or percentage restriction, would need to be determined experimentally for a larger set-up to confirm that the observations are sufficiently scalable. The team did not test for enough variables between 0.7 cm channel width and 0.3 cm channel width to confirm that 0.3 cm is the largest width that provides satisfactory results. Finally, there is a need for further research on the geometry of the obstacles and how this might affect the creation of dead zones.

Future Work

The trials already conducted have demonstrated the effectiveness of obstacles at the tops of the lower baffles . Next steps will entail analyzing the observations made and using the results to identify specific parts of the flocculator that the team can adjust and propose a design that will optimize the AguaClara flocculators currently used in the water plants.

Some parameters that might also affect the fluid flow through the flocculator and are worth studying are the geometry of the obstacles, the number of obstacles, and the location of the obstacles placed between the baffles. The team's current model utilizes a circular obstacle at the top of each lower baffle. The future team can test the model with different obstacle shapes and observe how the obstacle geometry influences the fluid flow and whether it reduces dead zones above the lowers baffles. The future team can also study how the number of obstacles and the location of each obstacle possibly affect the fluid flow in the flocculator and observe what specific settings maximize the utilization of the space between the baffles and eliminate dead spaces most effectively. The current model also has constriction on both sides of the lower baffle due to the circular geometry of the obstacle. The future team should test and analyze whether the constriction on the right side of the lower baffle is necessary at all, and based on the results, decide whether the flocculator only needs constriction on the left side of the baffle where the fluid is flowing up, or on both and left and right side of the baffles, where the water is flowing up and coming back down, respectively.

Additionally, the current model should be tested with a higher Reynolds number to reflect the conditions of the actual flocculator more accurately and observe results that might resemble more of what one would see in the flocculator used at the AguaClara water plants. The flocculator model should also be studied using clay solution and a post effluent sedimentation tube to analyze the influent and effluent turbidity and how this is affected by the presence of obstacles.

References

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