# Plate Settler Spacing Research Summer 2008

## Summer 2008 Research

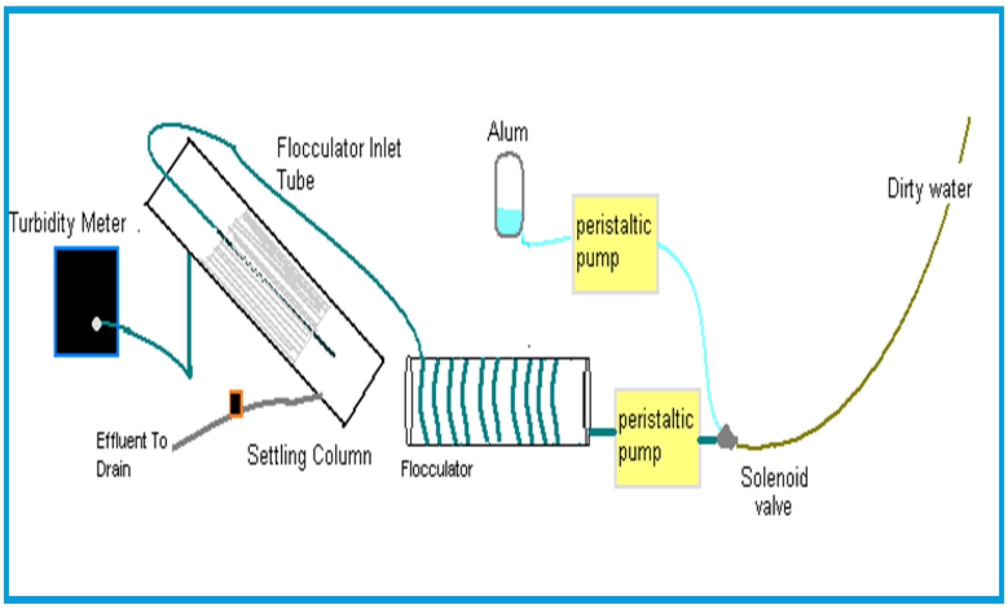
### Objectives

The purpose of this experiment was to determine the feasibility of improving sedimentation in the current AguaClara technology. The goal is to consistently produce effluent water with an effluent turbidity of less than 1 NTU. Currently, the AguaClara technology makes use of lamella, spaced apart by a distance on the order of 5 cm, in its sedimentation tanks. This study sought to determine the feasibility of significantly decreasing the spacing between plate settlers to create a filter-like media and create less than 1 NTU water. A set up was developed to collect turbidity data for a range of filter-like media spacing, to help determine the optimal spacing. To determine if filter-like media in place of lamella is practical in the sedimentation tank, the frequency in which clogging occurs was also noted. In addition, a cleaning method needed to be devised to ensure proper maintenance. This is because the AguaClara technology makes no use of electricity, and so the "filter media" needs to be able to be cleaned without the pumping water back up to backwash.

### Methods

The set-up and method was similar to the CEE 453 project from Spring 2008.

#### Schematic




**Schematic of Apparatus Setup**

As seen in the above schematic, a lab bench scale sedimentation and flocculator set-up was assembled for the experiment. The raw water, kaolin clay mixed with tap water, was mixed with a aluminum sulfate at dosage of 45 mg/L. This water was then pumped into the tube flocculator. The end of the flocculator flows into the sedimentation tank at a flow rate of 272 mL/min. The tube enters the from the top of the sedimentation tanks, passes through the straws to the bottom of the sedimentation tank, allowing the water to flow upward uniformly. The outlet above the straws draws the "clean water" out of the tank and into a turbidity meter.

#### Design Parameters

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| Old Apparatus Setup | New Apparatus Setup |
|---|---|
| d = 1/4 in | d = 3/8 in |
| G = 129.1/s | G = 35.7/s |
| $\Theta$ = 68.77 s | $\Theta$ = 156.77s |
| $G\Theta = 8.996 \times 10^3$ | $G\Theta = 5.596 \times 10^3$ |
| $V_{up}$ = 53.3 m/day | $V_{up}$ = 51 m/day |
| Q = 292 mL/min | Q = 272 mL/min |

**Table 1:** Design parameters used in the old(initial) and new apparatus setup.

The table above contains information in regards to the tube flocculator inner diameters (d), velocity gradients (G), residence times (), flow rates (Q), and other important parameters used in the old and new apparatus setups for the sedimentation prototype. For both setups an Alum dosage of 45 mg/L was used. Additionally, parameter values were based on a flocculator length of 10 meters and a sedimentation tank angle of 60 degrees. It is important to note that the value for the velocity gradient G must be 5000/s at minimum for AguaClara plants and in both setups the G calculated is above 5000. Also, the $V_{up}$ values for both setups do not exceed the 70 m/day maximum for AguaClara plants.

## Initial Apparatus Setup

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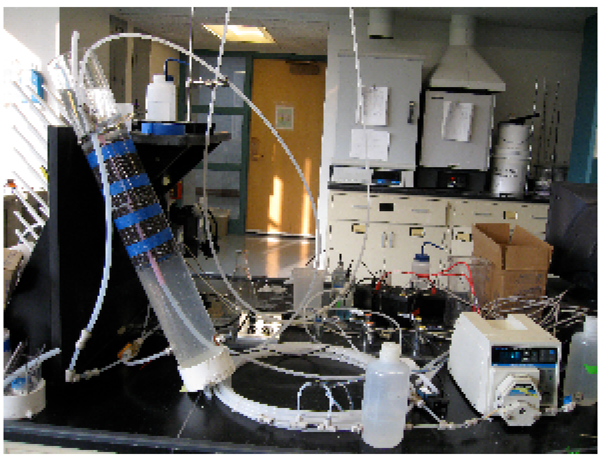

**Initial Apparatus Setup**

The initial apparatus set up was run by Process Controller which had functions set in place for when the system would turn on, off, or drain. It also included a pressure sensor that would control the flow rate of the system. It was found that the pressure sensor was unreliable and sensitive to changes in the environment. Additionally, the flocculator for this setup led to a high velocity gradient (G) of 129.1/s, which is much higher than the desired G of 20 /s. This led to the formation of very small flocs.

## New Apparatus Setup

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**New Apparatus Setup**

In the New Apparatus Setup the diameter of the flocculator was increased. This allowed for an increase in floc size and a significantly lower velocity gradient (G) of 35.7/s. Ideally, a G around 20/s is wanted, however, such a velocity gradient may have caused other important parameters to be too low. Additionally, the flow control system was changed to utilize a peristaltic pump allowing for a more stable system.

## Equations

The following equations were used to determine critical settling velocity of each straws type, the velocity gradient of the flocculator, and the residence time of the flocculator.

Critical Settling Velocity

$$V_c = \frac{bV_{up}}{Lsin\alpha cos\alpha + b}$$

Velocity Gradient

$$G = \frac{64Q}{3\pi d^3}$$

Residence Time

$$\theta = \frac{\pi d^2 L}{4Q}$$

## Length and Diameter Values

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| Type | Straw Diameter (D) | Straw Length (L) | L/D |
|---|---|---|---|
| 1 | 12mm | 198mm | 16.5 |
| 2 | 5mm | 196mm | 39.5 |
| 3 | 3mm | 278mm* | 92.667 |
| None | No straws (100mm) | 689mm | 6.822 |

**Table 2:** The data above shows length(L), diameter(D), and ratio of L/D values for each straw setup.
*The straw length was doubled because two straw packs were used in the sedimentation tank.

In regards to the length and diameter values, the table above shows a wide spread of L/D values. The no straws situation uses the measurements of the sedimentation tank. Additionally, in the case of the type 3 straw situation, the length of the 3mm diameter straws were significantly smaller than the other straws. To solve this issue, two packets of straws were used in the sedimentation tank so that the length for the 3mm straws could be doubled.

## Critical Settling Velocity Values

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| Type | Diameter of straws (b) | Length of straws(L) | Vc |
|---|---|---|---|
| 1 | .012m | .198m | 6.362 m/day |
| 2 | .005m | .196m | 2.837 m/day |
| 3 | .003m | .278m | 1.240 m/day |
| None | .100m | .689m | 12.899 m/day |

**Table 3:** The data above shows the critical settling velocities of each straw setup

Critical settling velocities demonstrate the shortest amount of time it takes for a particle to settle out. The $V_c$ values above show how long it takes for particles to settle out in each straw setup situation. In comparison to the AguaClara plants which have a maximum critical velocity of 10 m/day, only the no straws situation exceeds this value.

## Straw Bundles

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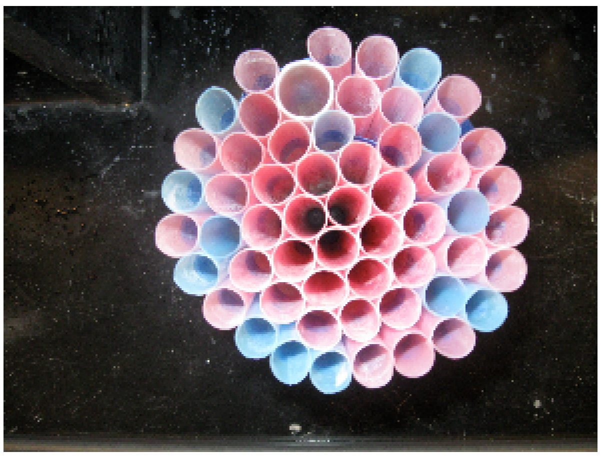

**Type 1 Straws - 12mm**

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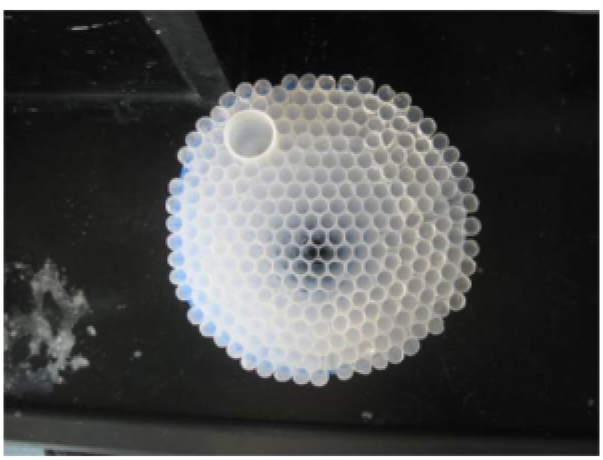

**Type 2 Straws - 5mm**

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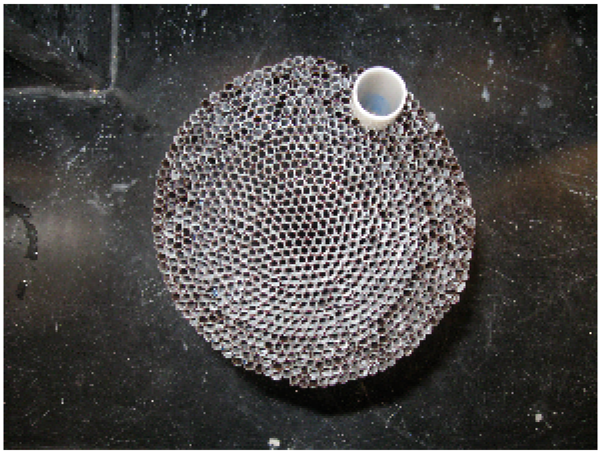

**Type 3 Straws - 3mm**

For the initial straw setup, each straw bundle used one 12mm straw a tube for the inlet tube of the flocculator to pass through. However, when the straw set up changed, the outer diameter of the flocculator exceeded 12mm. Therefore, a 9/16ths inch inner diameter tube was ordered to accommodate the 1/2 inch outer diameter tube used in the new straw setup.

## Results and Discussion

### Matrix of Experiments

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| Type | Straw Diameter | Floc Blanket | No Floc Blanket |
|---|---|---|---|
| 1 | 12mm | Type 1 with Floc Blanket | Type 1 without Floc Blanket |
| 2 | 5mm | Type 2 with Floc Blanket | Type 2without Floc Blanket |
| 3 | 3mm | Type 3 with Floc Blanket | Type 3 without Floc Blanket |
| None | 101mm | No Straws with Floc Blanket | No straws with no Floc Blanket |

**Table 4:** The data above is a matrix of the experiments performed for the Sedimentation Prototype.

As shown by the table above, 8 experiments total were planned, however the tests on the type 3 straws have not yet been completed.

At this point, tests have only been performed on the 12 mm and 5 mm diameter straws. Three trials were run on the two types with and without a floc blanket. Due to some problems with the system there was a limited about of useful data.

### Experiment Obstacles

#### Maintaining a floc blanket

While testing with the floc blanket it became clear that there was a problem with flocs settling out, decreasing the volume of the active suspended sludge. As seen in the image below, much of the sludge would settle along the incline of the settling column. This limited the effectiveness of the floc blanket, particularly in the trials with the 5 mm diameter straws.

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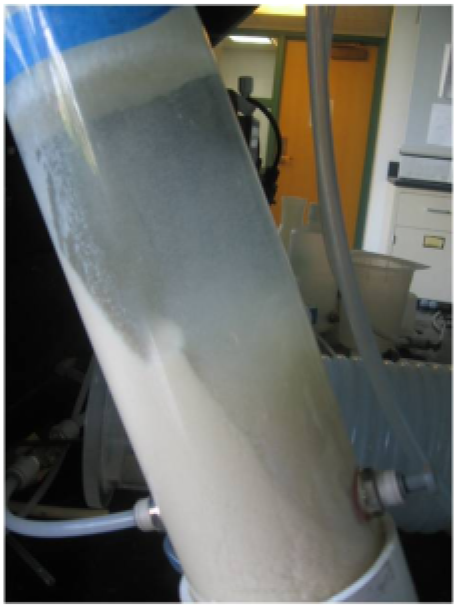

**Floc Blanket**

### Turbidity meter readings

The horizontal tube connected to outlet of the settling column was tilted upwards which cause a sort of siphoning effect. The tube would fill with water and then empty, creating an intermediate flow of water into the turbidity meter. This created large and frequent jumps in the turbidity meter readings. A large portion of the data collected with this problem is difficult to read.

### Clogged Straws

In the 5 mm diameter experiments the straws clogged. This occurred within 15 hours of the final trail without a floc blanket. Once clogged flocs being pumped into the system would push the flocs settled out in the straws to the top, create a floc formation on top of the straws, as seen above. Particles would eventually float off the top of the floc blanket that formed on top increasing the turbidity of the effluent water.

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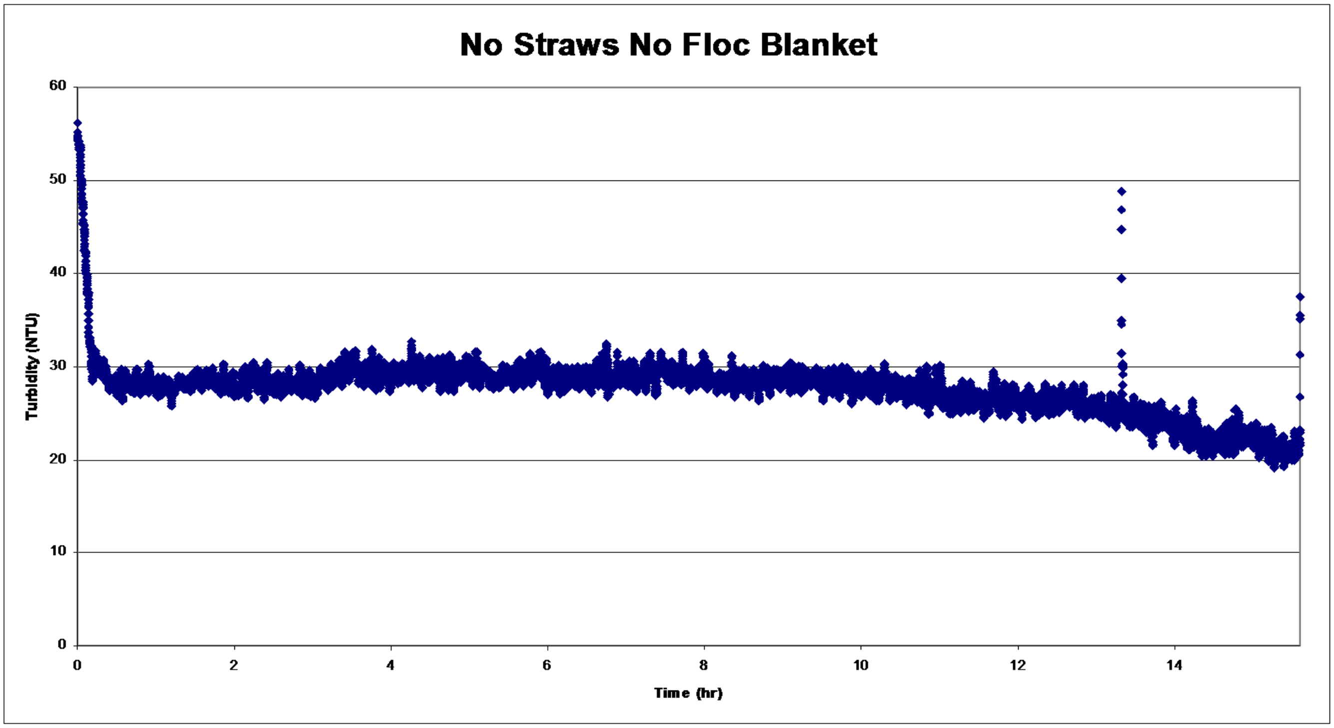
**Clogged Straws**

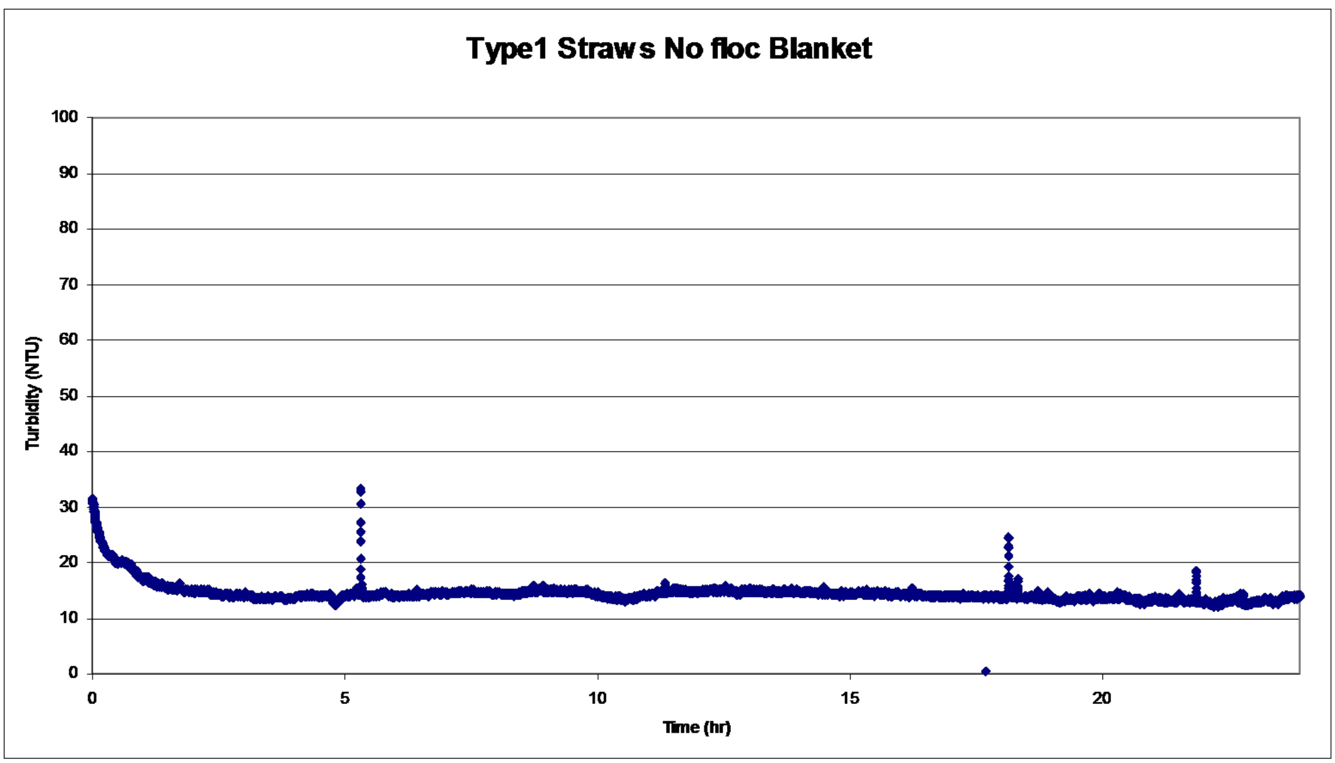
## Experimental Trials

### No straw trials.

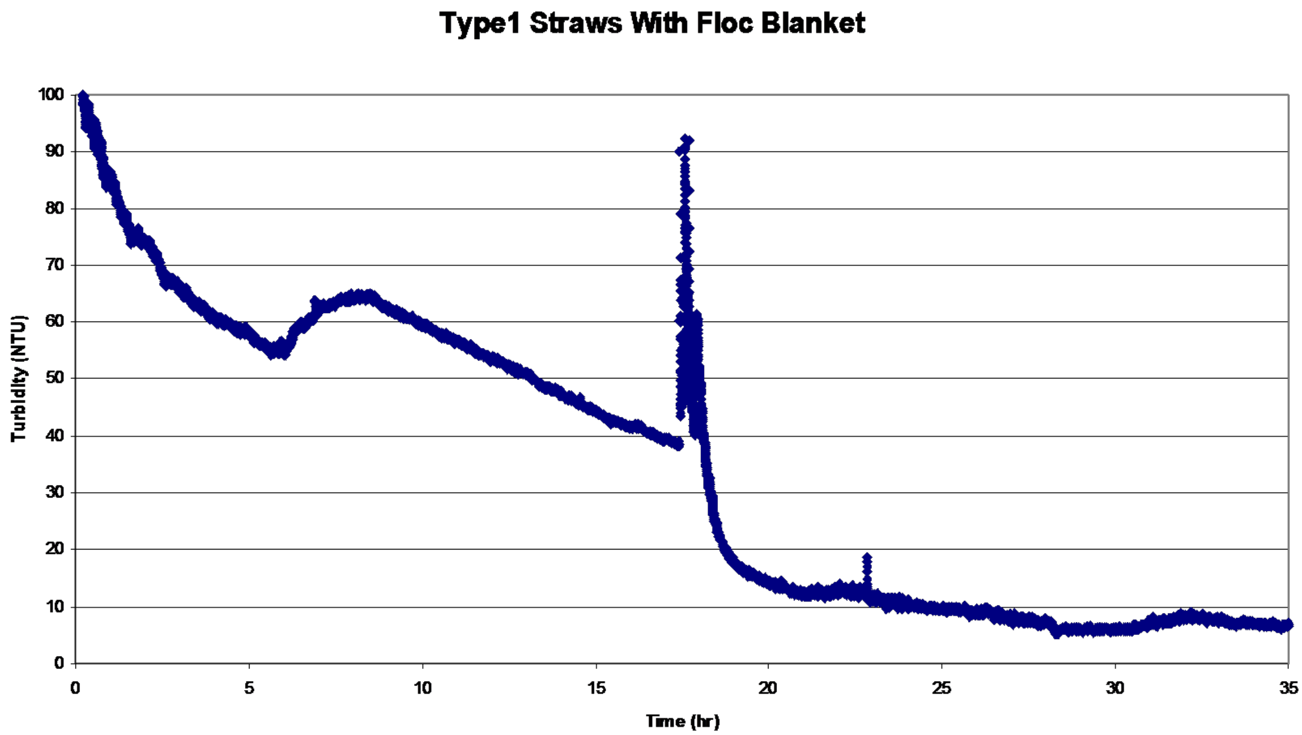
It is important to first note that the raw water turbidity during this test was around 200 NTU. The effluent turbidity remained between 30 and 20 NTU, and the average percent removal was around 86.4%.




## Type 1 Straw Trials

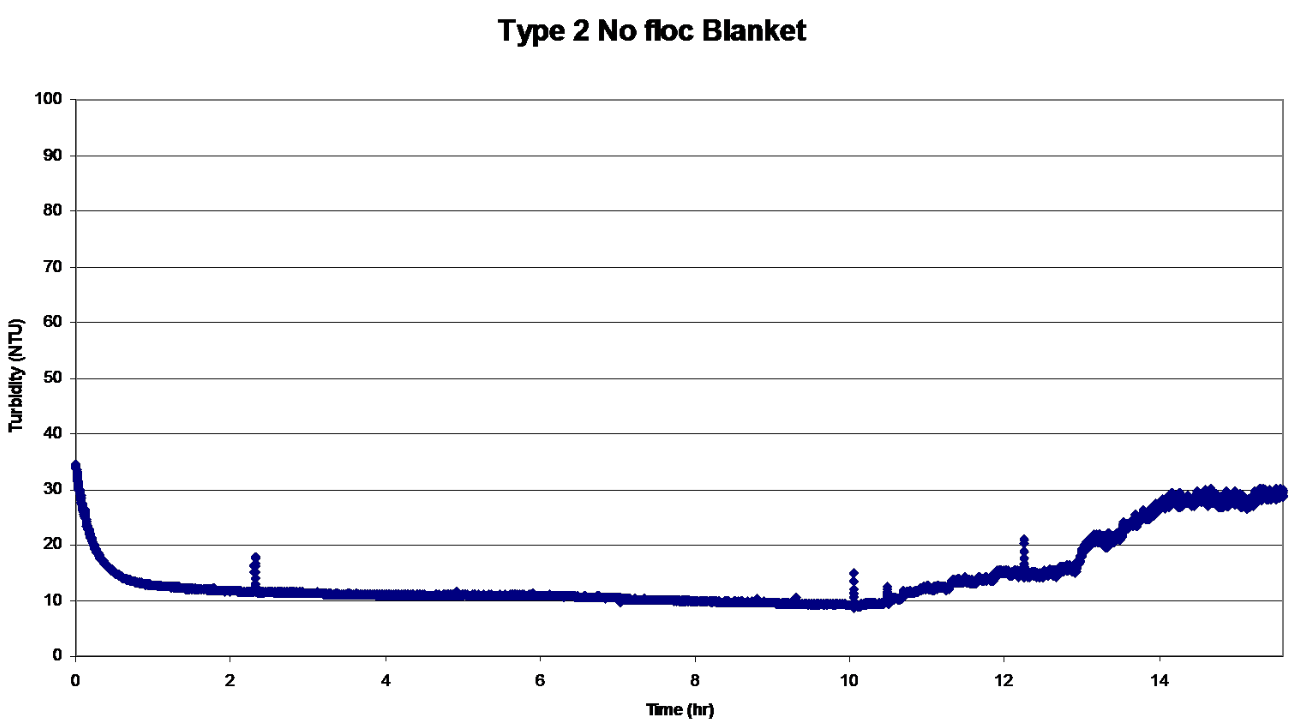



This trial for the largest diameter straws (12 mm) maintained a steady effluent turbidity of 15 NTU. The average percent removal for this trial was 82%.

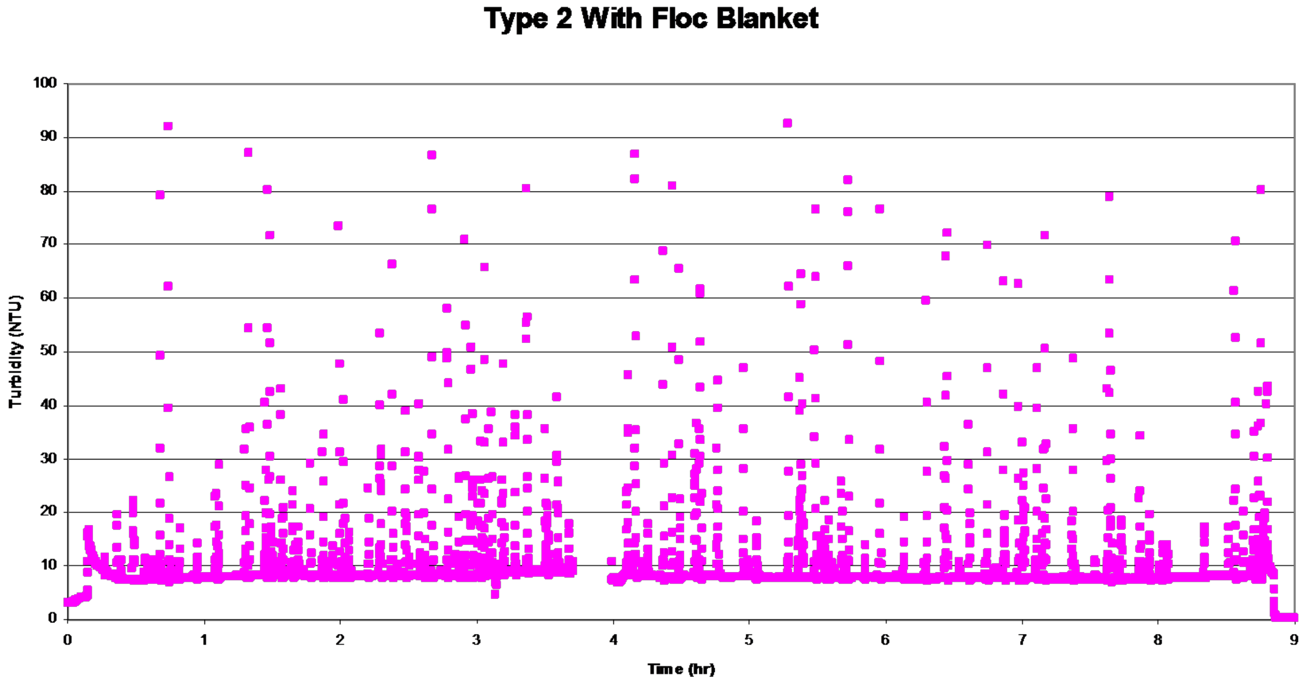



The effluent turbidity with the floc blanket was much less stable for the first 20 hours. After the 25th hour the effluent turbidity remained around 9 NTU. The Average percent removal was 90%.

## Type 2 Straw Trials




—The type 2 straws yielded an effluent turbidity of around 12 NTU until around the 11th hour. The increase in turbidity could have occurred due to the clogging of the straws. The average percent removal for this trial was 86%.




As mentioned before the turbidity meter readings for some of the data was jumpy. Not unlike the 12 mm diameter straw trials, the 5 mm trial performed better with a floc blanket than with out. The effluent turbidity of this trial remained around 8 NTU. The percent removal for this trial was 91%.

## Conclusions

From the limited available data it can be determined that straws perform significantly better than the settling column tube. There is a slight trend of lowering turbidities as the critical velocities of the system decreasing, which was expected. The combination of the floc blanket and lower Vc values seem to produce the most favorables results of lower effluent turbidity readings. Due the problems with maintaining floc blankets, more testing should be done to determine the effectiveness of the floc blankets.

The clogging of the straws indicates better removal of particles from the water. The particles are being removed from the water despite the higher turbidity readings. This may be due to the significantly lower critical velocities found in the smaller straws. The effluent turbidities in all of the experiments, however, were unfavorable. Improving the flocculator and the overall experimental setup may help to produce lower effluent turbidities.

## Future Work

In terms of the immediate future (the last few weeks of summer), testing will continue on the type 3 straws. One of the major improvements to the experimental set will be the improvement of flocculation by lengthening flocculator, thus increasing G. Another improvement to the flocculation will be increasing the number of changes in flow within the flocculation, hopefully creating my collision of particles and increasing floc size. To solve the problem of the straws clogging a lower alum dosage of around 25 mg/L will be used instead of the 45 mg/L. Additional tests will be conducted without the use of a floc blanket, due to difficulties with maintaining a stable floc blanket in the previous tests. Future work may include the use of floc blankets since they do contribute to lower effluent turbidity values.

It may be beneficial to examine the head lose through the straws given laminar flow. The Hagen-Poiseuille equation can be used to find the head loss.

To determine the feasibility of implementing these changes in the sedimentation tanks in Honduras, research must be done on the availability of materials with similar geometry. This material could be purchased and tested in the pilot plant set up at the Cornell Water Treatment Plant.