CDC Experiment- Surface Foam

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Determining the Cause of Surface Foam Experiments

Experimental Set-Up

In an attempt to recreate surface foam in a lab setting, similar to that found in AguaClara Plants in Honduras, we first had to recreate a similar design in the lab. We did so by first having a tank which mixed tap water and clay in order to have a constant turbidity of approximately 100 NTU. This tank represented the incoming plant water. Water from this tank was then mixed with Natural Organic Matter (NOM) and sent into Tank 2 which simulated the rapid mix tank and first baffle of the flocculation tank. Once in this tank, the turbidity of the water was once again measured, and alum was dripped onto the surface of the water. The water in the rapid mix side of tank 2 was mixed with a stirrer before traveling into the first baffle portion of the tank. It was here that the water was able to settle a bit and a webcam took pictures of the surface water every two minutes to determine if surface foam was created. When an aerator was added, it was placed in the first baffle portion of tank 2.

In order to calculate the energy dissipation rate at the rapid mix due to the tubing, first we calculated the head loss (h) of the tubing using the equation,

$$h = \left(\frac{Q}{ka}\right)^2 \frac{1}{2g}$$

Then we calculated the residence time (θ) using,

$$\theta = \frac{d_{tube}}{v}$$

Where,

$$v = \frac{Q}{a}$$

Finally energy dissipation (ε) was calculated using the following equation,

$$\varepsilon = \frac{gh}{\theta}$$

Where:

h= the head loss due the tube,
Q = is the flow rate in mL/min
a = the area of the tube
k = constant magnitude of 0.6
g = gravity
θ = the residence time
d_{tube} = the length of energy dissipation of the jet, which was estimated on the length scale of the diameter of the tubing.
V = speed the flow
ε = energy dissipation

We obtained the same order of magnitude for energy dissipation as the AguaClara plants.

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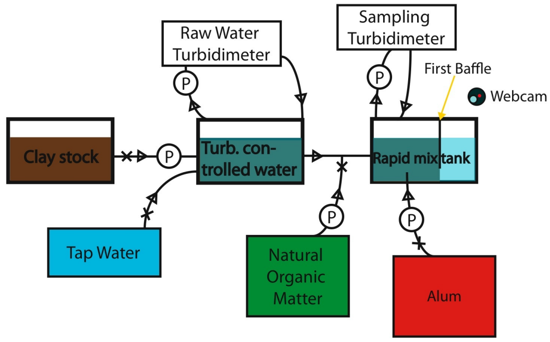

Illustration of Experimental Setup

Our experiment included the following parameters: Coagulant(Alum) dosage, concentration of Natural Organic Matter (NOM), location of alum addition, aeration of water and addition of a surfactant. In the first week of our experiment, we tested for alum dosage in order to determine whether it caused foam formation. Alum dosages of 35 mg/L, 45 mg/L, 55 mg/L and 65 mg/L were added to the rapid mix chamber.

The following week the group used Humic Acid in order to determine the effects of NOM on surface foam formation. Varying the dosage at 1mg/L, 2mg/L, 5 mg/L and 10 mg/L, Humic acid was mixed in the rapid mix chamber with 45 mg/L of alum.

After deciding to add an aerator, we kept the parameters the same as in the NOM experiments, however we added an aerator to the first baffle portion of tank 2.

Finally to study the effect of hydraulic jump on bubble formations, we varied the height of the water fall at 12.4cm, 14cm, and 15.4 cm. We used these heights because they were approximately equal to the distance that water would be falling in the LFOM.

After determining both the cause of the foam and theoretical ways to prevent the water from aerating, our next task was to produce designs for retrofitting the current AguaClara plants in operation.

Results & Discussion

Our first experiment sought to determine whether overdosing alum could aid in the formation of surface foam. After dosing the water with varying alum concentrations, it was determined through observation that no foam was formed.

Although the foam was not formed, this information was crucial to our research. Not only did it minimize the list of potential foam formation factors, it also help build our understanding of foam formation. As a result of foam not forming due to alum addition at the surface of the water, we also were able to rule out alum addition under the water surface as intuitively it was a solution to the form formation.

Our second experiment sought to determine whether or not the addition of Natural Organic Matter (NOM) contributed to the formation of surface foams. At all concentrations of Humic Acid, we again found there was no surface foam formed. Although the NOM did lower the surface tension better enabling bubbles to form, we believe they did not form due to a lack of air bubbles which naturally are found in AguaClara plants. As a result, we modified our experiment to include an aerator to provide them.

In our next experiment, we again varied the concentration of NOM but included an aerator to provide bubbling directly into what would be the first baffle spacing. At concentrations below 2 mg/mL we found that no foam was formed. However at higher concentrations of Humic Acid, we found that large bubbles would rise and then quickly pop in the center of the tank. In the meantime, smaller bubbles would form around the edges of the tank and were slightly more persistent as seen in Figure 2.

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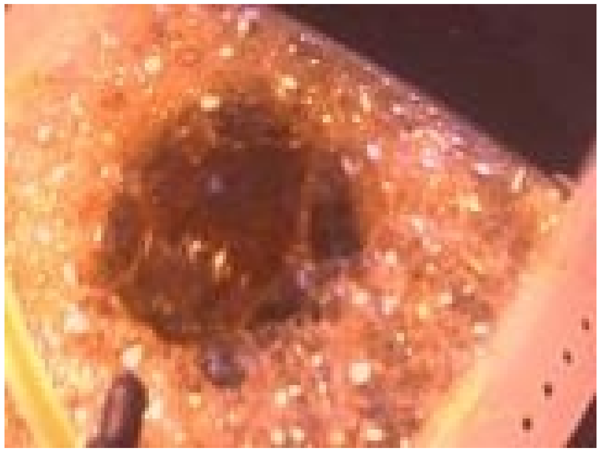

Figure 2: Surface foam as a result of Humic Acid Addition

Bubbles form when water molecules form bonds around air pockets. A surfactant is generally an organic molecule that has both hydrophobic and hydrophilic ends. While surfactants reduce the surface tension of water they also form micelles in water which helps to stabilize air bubbles and prevent them from aggregating. The concentration at which surfactants begin to form micelles is known as the critical micelle concentration or CMC. Although the addition of humic acid did reduce the aggregation of air bubbles it still occurred. This resulted in large, non persistent air bubbles that formed a foam at the surface of the water. This may be attributed to not reaching the CMC, however using higher concentrations of humic acid would not accurately replicate plant conditions.

Although, a surface foam was formed at concentrations of Humic Acid greater than 2 g/mL, it was not the foam that is found in AguaClara plants. The foam we created in lab contained large non-persisent bubbles, however the foam we sought to create contained small persistent bubbles similar to natural foams found in rivers and lakes. At this point we began searching for a stronger surfactant to further prevent the aggregation of bubbles, thus replicating the foam found in Honduran AguaClara plants.

In order to support our hypothesis, we added soap to our last experiment with Humic Acid simply to see if would create the surface foam we wanted. We added soap because its molecular composition is similar to that of fatty acid surfactants found in nature. We found that the soap caused a persistent foam, similar to that found in AguaClara plants and can be seen in Figure 3 below.

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Figure 3: Surface foam after the addition of Dial soap

In our bucket without holes experiment, we found that at heights less than 14cm we can prevent a hydraulic jump. A hydraulic jump normally causes a significant loss of energy and the production of turbulence often resulting in the entrainment of air. This experiment helps us determine an ideal height for our cup design. Although we have eliminated this cup design (see retrofit designs page for details), if we were to continue looking into this theory it would be beneficial to start by testing smaller hydraulic jumps.

No labels