

Observing the effect of natural organic matter on kaolinite and aluminum sulfate flocs within a model AguaClara plant

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Abstract

The effect of natural organic matter in an AguaClara plant was observed and analyzed. Modeling humic acid as natural organic matter and kaolinite as non-natural organic matter with aluminum sulfate as the coagulant, it was found that water purification was moderately improved in a low turbidity environment at higher humic acid concentrations, while lower concentrations yielded more scattered results. Additionally, it was found that humic-alum flocs did not create a floc blanket but managed to yield comparable results to kaolin-alum flocs that did create a floc blanket in a trial with raw water of 25 NTU. It is expected that at higher turbidities, humic acid would not follow this trend but instead would match the more traditional notion that higher humic acid concentrations yield less successful sedimentation processes.

1 Introduction

Previous research has revealed that kaolinite-aluminum sulfate flocs can induce floc roll up in AguaClara plants and are a failure mechanism in plate settlers, but realistic raw water conditions also include natural organic matter (NOM). Natural organic matter can be best recognized as a key contributor of color and odor in raw water. Its by-products can be harmful to humans and also impede upon the purification process (Qin et al., 2005). Increased concentrations of natural organic matter have been shown to decrease floc strength and significantly worsen sedimentation success, which makes it all the more pertinent to reconsider AguaClara's plate settler design to include NOM (Zhong et al., 2011). The presence of NOM creates a physical and chemical change in flocs, as flocs coated in NOM have less successful further floc formation, decreasing

the likelihood of a strong floc blanket (Wilkinson and Reinhardt, 2005). NOM flocs also tend to be less dense, which could result in intensified floc roll up in AguaClara plate settlers. Understanding the floc roll up response to NOM and NOM-kaolin-alum flocs will allow continued assessment of the ideal spacing between plate settlers. The objectives of this paper were to determine how much NOM, if any at all, the current model AguaClara plant could purify, and then to offer background data for further design improvements and adjustments to the plate settlers.

2 Materials and methods

2.1 Chemical choices and concentrations

Humic acid was used as a model for natural organic matter, while kaolin represented suspended non-organic matter in raw water. Aluminum sulfate (alum) was used as the coagulant because it is the choice coagulant of many actual AguaClara plants; however, it has been observed that alum has a lower success rate (in comparison to other coagulants such as ferric chloride) in the purification of NOM (Zhong et al., 2011). Due to this fact, alum plant dosage was set at 150 mg/L to compensate for its lower efficiency and to ensure that the coagulant dosage would not become a limiting factor in flocculation and sedimentation.

2.2 Apparatus

Process control software controlled the experiment. 10 g/L clay solution was added into a raw water reservoir until the desired turbidity was achieved, while humic acid of the chosen plant dosage was added at a constant rate of 4.3 mL/min. 150 mg/L alum plant concentration solution was then added to raw water at a rate of 3.9 mL/min, after which the water flowed into a coiled tube flocculator. After going through the flocculator, the water flowed into a sedimentation column and formed a floc blanket. Once the floc blanket had been solidly formed, the tube settler and floc blanket turbidities were measured. In this model, the tube settler mimicked the plate settlers in an actual plant. Turbidity data was recorded every second. The tube settler pump velocity was set at the lower velocity of 3.785 mL/min because at a higher velocity, the quarter-inch diameter tube settler could easily draw up the less dense humic flocs.

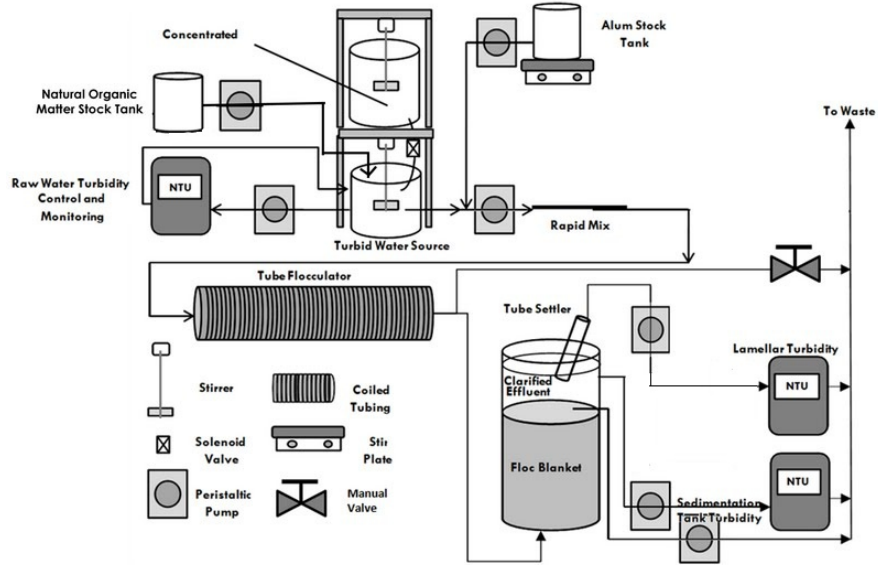


Figure 1: Plate settler spacing team model AguaClara system

2.3 Humic-alum flocculation experiment

To test for the worst case scenario, the humic acid plant concentration was set at 40 mg/L (an amount unrealistic to find in actual raw water) and the turbidity was kept at 0 NTU; without kaolin, the flocs created were essentially those most difficult for the current plant to handle. Also, if no floc blanket formed, it could be concluded that it is not possible to purify humic acid/NOM alone through traditional sedimentation processes.

2.4 Humic-kaolin-alum flocculation experiment

Raw water turbidity was maintained at 25 NTU with varying humic acid plant concentrations of 2.5 mg/L, 5 mg/L, and 10 mg/L. The reason for choosing to vary humic acid dosage rather than turbidity was due to the fact that the chosen situation was theoretically more difficult for the current system to handle. Having a higher turbidity would make the humic acid less prominent and more closely mimicked conditions in which the system has succeeded. It was expected to find that lower humic acid plant concentrations would yield better tube settler performance than higher humic acid plant concentrations because having fewer less dense flocs would decrease the possibility of inadvertent floc roll up.

3 Results and discussion

3.1 Purification of humic-alum flocs

The high humic acid plant dosage of 40 mg/L created large, low density, highly colored flocs which did not create a floc blanket. Tube settler performance was consistently negative, and the average turbidity difference between floc blanket effluent and tube settler effluent was -11.59% (Equation 1).

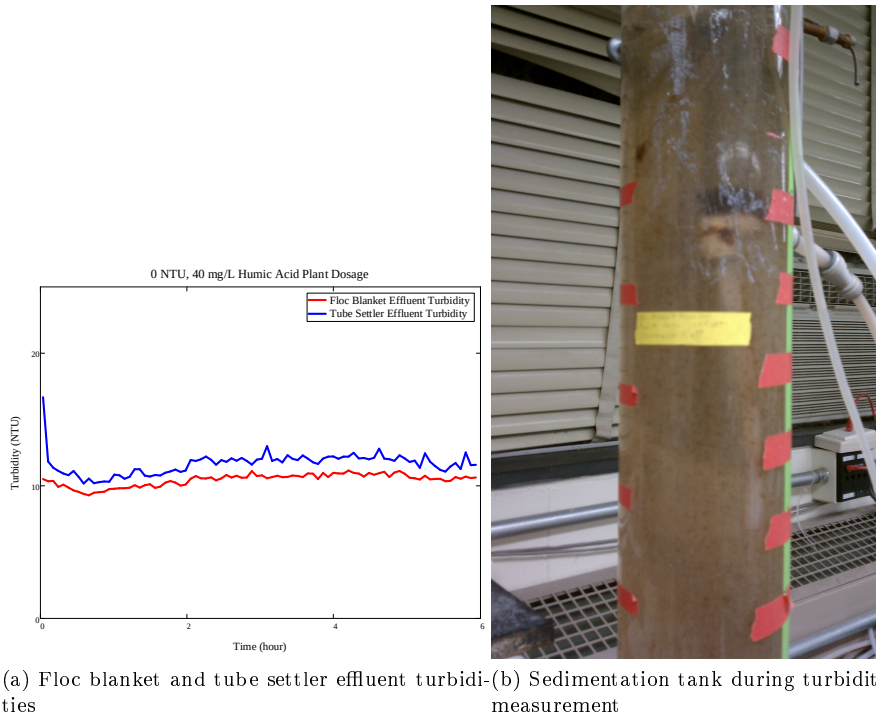


Figure 2: AguaClara model response to 0 NTU, 40 mg/L humic acid plant dosage

$$PercentageDifference = \frac{FlocBlanketTurbidity - TubeSettlerEffluentTurbidity}{FlocBlanketTurbidity} \quad (1)$$

From this experiment, it was determined that any floc blanket that might form in an experiment containing humic acid would be a result of other substances, like kaolin. Additionally, it was discovered that tube settler performance, although negative, was not as poor as expected because high concentrations of humic acid yield very large flocs which were unable to be drawn up by the quarter-inch diameter tube settler.

3.2 Effect of humic acid on kaolin-alum flocs

All trials yielded floc blankets which grew progressively less colored as the humic acid plant dosage decreased.

The average turbidity difference between floc blanket effluent and tube settler effluent was -20.07% for 10 mg/L humic acid plant dosage, -17.17% for 5 mg/L humic acid plant dosage, -34.79% for 2.5 mg/L humic acid plant dosage, and -24.62% for 0 mg/L humic acid plant dosage (Equation 1). The trial with raw water at 25 NTU and a humic acid plant dosage at 10 mg/L was the only trial in which the tube settler was successful for any period of time, which indicates floc roll up in all experiments.

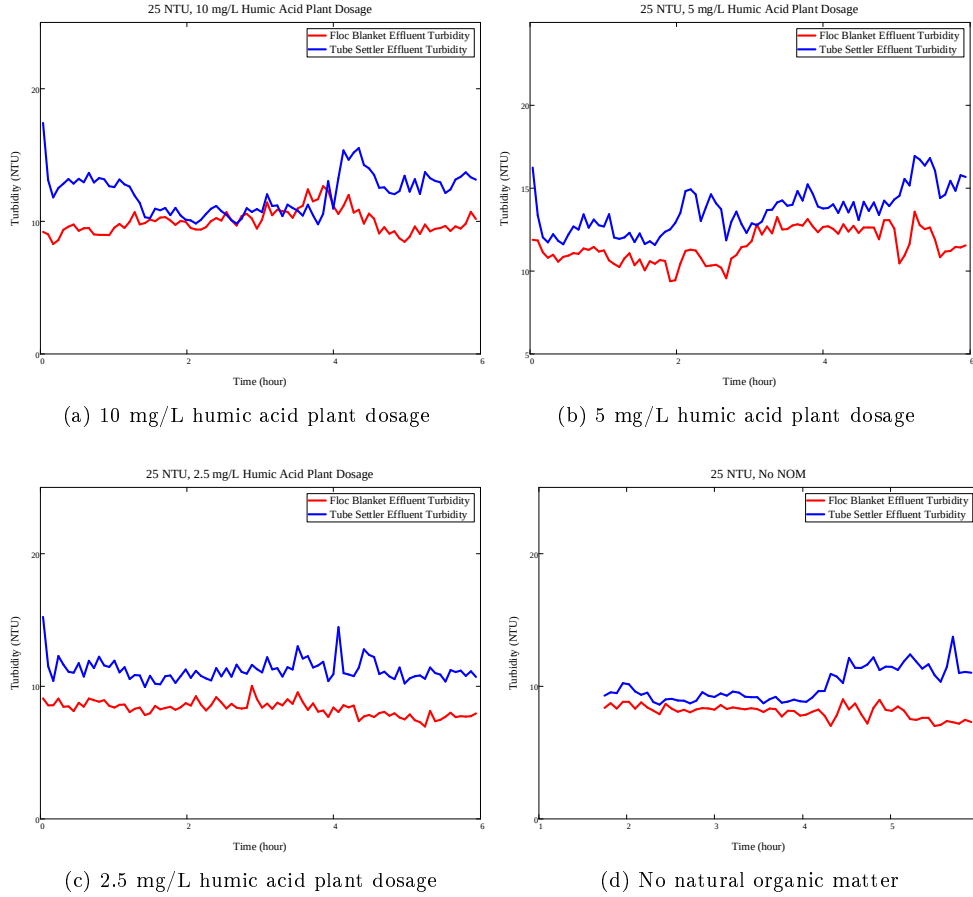


Figure 3: Floc blanket and tube settler effluent turbidities at 25 NTU with varying humic acid plant dosages

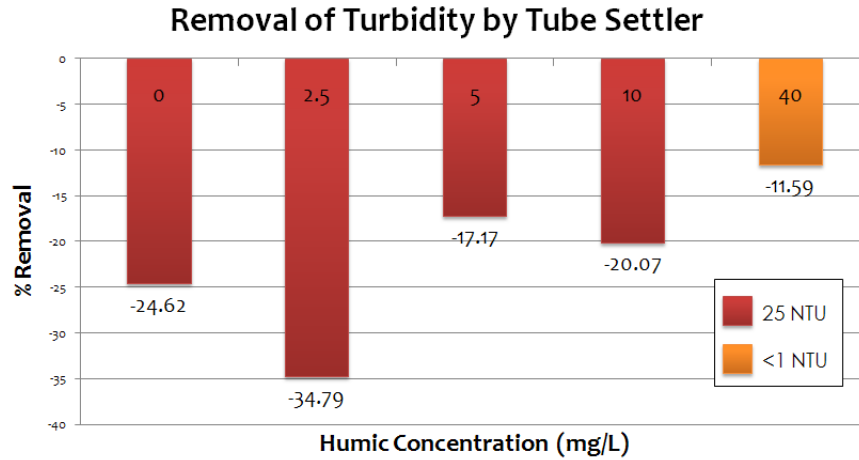


Figure 4: Percent removal of turbidity: average difference between floc blanket and tube settler effluent

Although it was expected that lower humic acid plant dosage would yield better tube settler performance, the low turbidity environment created a floc blanket with a low enough amount of “fill” that smaller flocs could escape with ease. When humic acid plant dosage was at the higher concentrations of 10 mg/L and 5 mg/L, flocs were less dense but also larger, essentially creating a more dense floc blanket because they were trapped in the blanket. At the low humic acid concentration of 2.5 mg/L, the flocs became smaller and because the floc blanket created at 25 NTU was fairly porous, flocs escaped the blanket and were drawn up by the tube settler, yielding poor tube settler performance. The trial with no humic acid attests to the porous floc blanket theory; the current AguaClara plant has been proven to purify raw water with only kaolin fairly successfully, and the negative tube settler results in that run demonstrate a weak floc blanket that makes the size of flocs very critical. The results of the runs including NOM seem to counter traditional notions about the negative effect humic acid has on fractal size and the sedimentation process, but it can be inferred that these properties hold true in cases where the turbidity is high enough to create a floc blanket that allows little floc escape.

4 Conclusions

The effect of humic acid in an AguaClara plant is highly dependent upon the conditions. Humic acid does not create a floc blanket on its own with aluminum sulfate, which puts great emphasis on turbidity levels because the kaolin is the key factor in fabricating a floc blanket. It was found that at low turbidities, a higher humic acid concentration actually improved the sedimentation process because the large flocs created more fill in the floc blanket, while a lower humic

acid concentration created small flocs that could easily escape the floc blanket and impede upon the sedimentation process. It is predicted that humic acid would behave in an opposite manner at higher turbidities and may also be purified out of raw water more easily with different coagulants such as ferric chloride or polyaluminum chloride.

Acknowledgements

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