Floc Modeling: Floc Saturation in Floc Filter Clarification

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Abstract

Understanding the distribution of floc saturation is important for modeling floc sweeping performance in AguaClara clarifiers. Tracking the movement of flocs can aid in characterizing the spatial distribution of floc saturation. The current study evaluates whether the movement of flocs in the clarifier can be tracked using colored tracer flocs in a bench-scale setup. This information will be incorporated into the clarification model and inform future design decisions related to clarification in AguaClara plants.

Introduction

Flocculation & Clarification Processes

Flocculation combines primary particles into larger aggregates called flocs.

Clarification (Fig. 2) allows the newly formed flocs to settle and separate from the treated water. AguaClara plants utilize a process called floc sweeping, where previously formed flocs capture additional primary particles in a suspension called a floc filter.

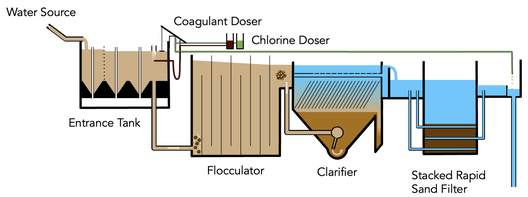


Figure 1. *The AguaClara water treatment process.*

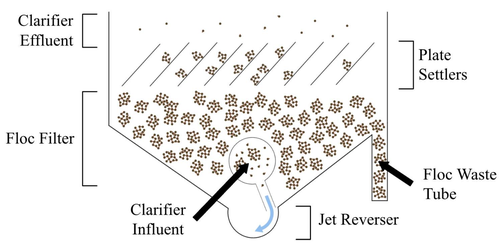
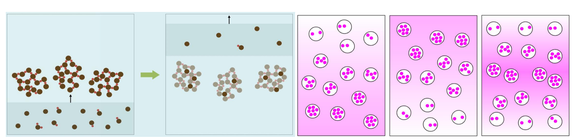


Figure 2. *AguaClara clarifier schematic.*



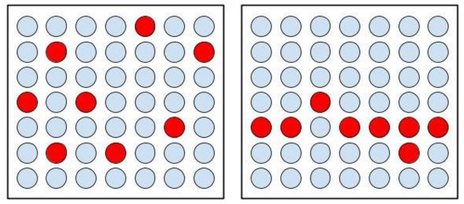
Figures 3, 4. Floc saturation in floc sweeping process (left) and varying spatial distributions of floc saturation (right).

Floc Saturation

As a floc captures primary particles, its pores fill, increasing the floc's saturation level and decreasing its ability to capture particles (Fig. 3). Spatial variations in floc saturation within the clarifier can affect particle removal efficiency in the clarifier (Fig. 4).

Methodology

To characterize the spatial variation of floc saturation in the floc filter, dyed tracer particles were used to determine if the flocs in the floc filter were well-mixed. A well-mixed floc filter would lead to a uniform distribution of floc saturation. The floc filter is hypothesized to be well-mixed.



Figures 5, 6. *Tracers in a well-mixed floc filter (left) vs a non-well-mixed floc filter (right).*

Tracer Procedure

First, uncolored flocs were formed in the tube flocculator using white kaolin clay and PACl. This accumulated in the clarifier to form a white floc filter. Then, Red-40 was added to the flocculator to create red tracer flocs. Red-40 was chosen due to its vibrance, availability, and negative charge. This negative charge allowed it to adhere to the positively charged PACl.

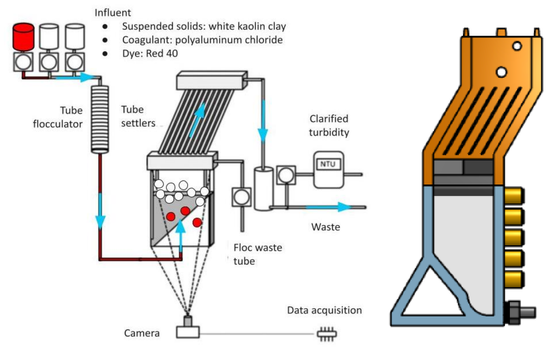
Additional Experiments

Additional experiments were also conducted to test the feasibility of using Red-40 as a tracer.

- **Proof of Concept:** Tube flocculator used to form flocs composed of only Red-40 and PACl.
- **Incorporating Kaolin:** Tube flocculator used to form red tracer flocs using Red-40 combined with white kaolin clay and PACl.
- **Jar Tests:** Jar tests performed with Red-40, kaolin clay, and PACl to determine dosages necessary to prevent Red-40 leakage.

Experimental Apparatus

A bench-scale flocculation and clarification setup (Fig. 7) was used to visualize floc filter dynamics. A helical tube flocculator was used for flocculation. The clarifier had sampling ports along the side and a clear acrylic front and back for convenient imaging, and its smaller size allowed for low hydraulic residence time.



Figures 7, 8. *Experimental apparatus (left) and bench-scale clarifier (right).*

Revised Clarifier Design

The original apparatus underwent three significant changes to allow for more exact data collection, improve acrylic adherence, and prevent leaks:

- Sampling inserts along the right side removed to simplify the fabrication process.
- Lip added to edge of acrylic plate to improve adhesion between the acrylic plate and clarifier body.
- The floc hopper sloped down to collect the sludge better, preventing excess build-up of flocs in the floc filter.

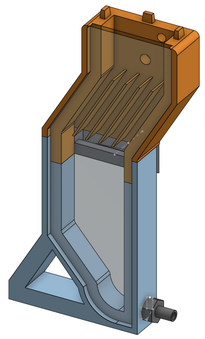


Figure 9. *Revised bench-scale clarifier.*

Results

Dying Flocs

The tube flocculator successfully produced Red-40 flocs (Fig. 10), confirming that dye could adsorb onto PACl in flocculator. It was also able to form tracer flocs composed mostly of kaolin clay with only a small amount of PACl and Red-40.

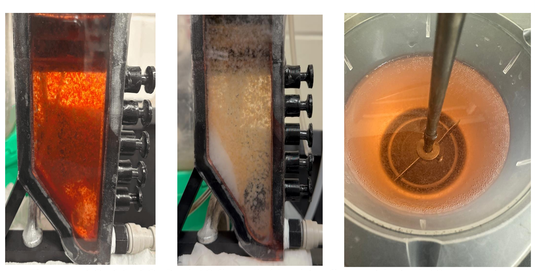
Using Tracers

Red-40 from the tracer flocs bled into surrounding flocs, causing non-tracer flocs to become indistinguishable from tracers (Fig 11). This was likely due to excess Red-40 dissolving into the water, which eventually adsorbed onto the non-tracer flocs. Jar tests were unsuccessful in determining a Red-40 and PACl dosage which formed visually dyed tracers without excess Red-40 in the water.

Methylene Blue

Jar tests were also conducted with methylene blue, a cationic dye, which showed formation of colored flocs without excess dye (Fig 13).

Red-40 proved unsuitable as a tracer dye for studying floc saturation. However, **methylene blue showed promise** due to stronger and more stable incorporation into flocs.



Figures 10, 11, 12. *Red-40 flocs (left), white flocs with Red-40 coloration diffused throughout the floc filter (center), and jar test with Red-40 (right).*

Future Work

- Following successful jar test results, replace Red-40 with methylene blue to color flocs.
- Track the movement of methylene blue-dyed flocs through the clarifier; image and analyze floc filter results.
- Resin print and assemble revised clarifier and begin utilizing it for experiments.

Figure 13. *Methylene blue-dyed flocs formed during jar tests.*

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Acknowledgements

Thank you to AguaClara Reach, Agua Para el Pueblo, AguaClara Cornell, Cornell Engineering, Cornell Project Teams, Andrew Pennock, and Dr. Monroe Weber-Shirk.

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