# Coagulant Dosing

## 2024FA

We design and run experiments to study the floc dynamics occurring in the clarifier.

Github: https://github.com/AguaClara/coagulant_dose_response.git

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# Background & Introduction

**Why Coagulant Dosing?**

- Coagulant is a sticky substance that enables floc formation during flocculation and primary particle filtration during clarification.

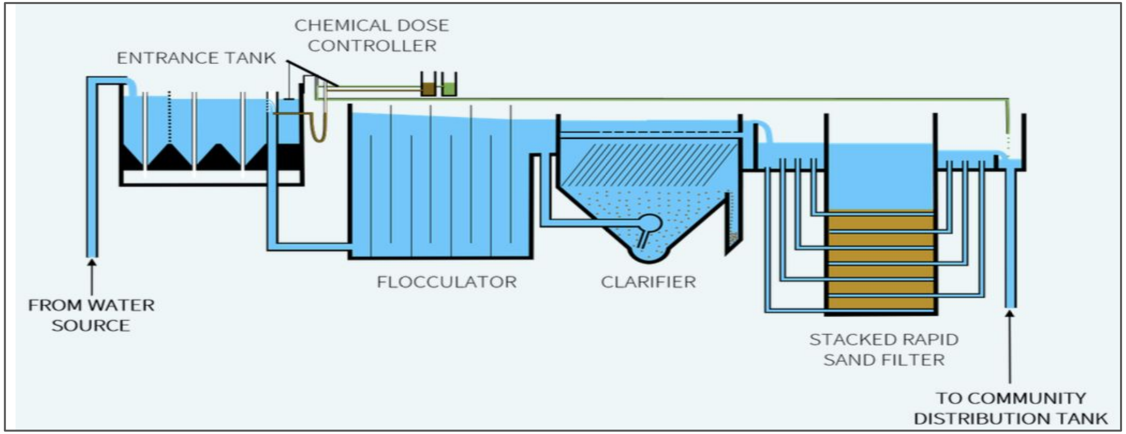


***Figure 1.*** *AguaClara water treatment process*

# Background & Introduction

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**Why Automate Coagulant Dosing?**

- Coagulant is manually dosed by full-time plant operators
  - Leads to high labor costs which presents a significant challenge for low-income communities.

- Automated dosing can increase access to drinking water treatment technology.

# Background & Introduction

To automate coagulant dosing, a deeper understanding and physical model of particle dynamics during flocculation and clarification is required.

**Flocculation Model**

- Developed by Pennock et al. in 2018
- Describes aggregation of primary particles into flocs in the flocculator

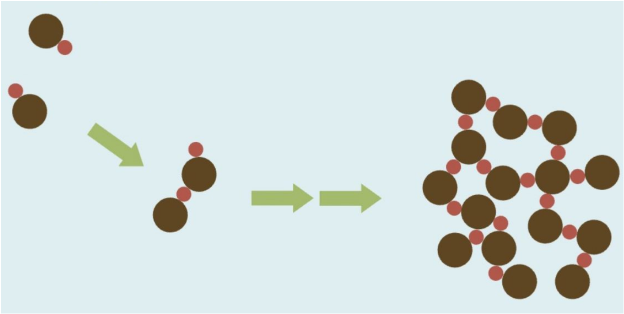

***Figure 2.*** *Particle aggregation during flocculation*

$$C_{flocculated} = \left(\frac{C_{coagulant}}{k_{pf} C_{influent}} + C_{influent}^{-2/3}\right)^{-3/2} \text{ where } k_{pf} = \frac{3}{2\pi k k' G\theta}\left(\rho\frac{\pi}{6}\right)^{2/3}$$

# Background & Introduction

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To automate coagulant dosing, a **physical model** of clarification is required.

# Background & Introduction

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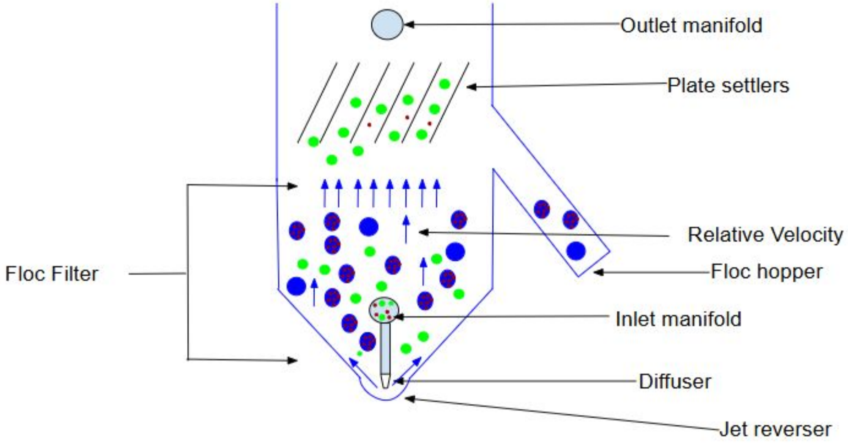


***Figure 3.** AguaClara clarifier*

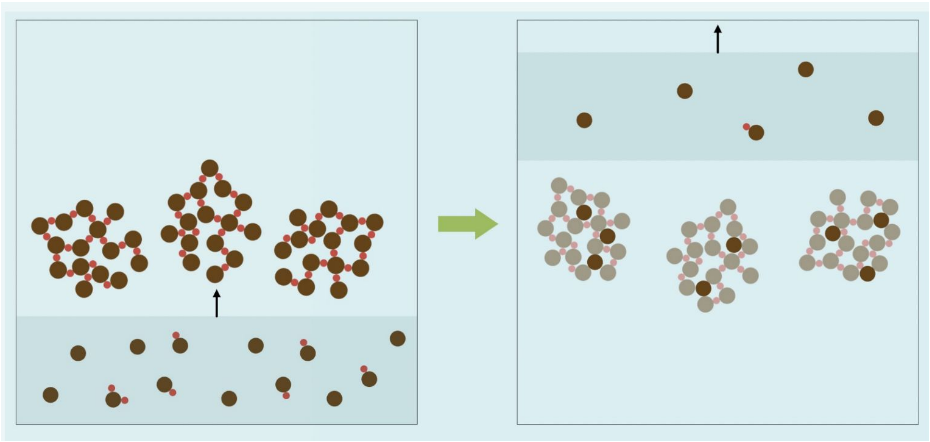

***Figure 4.** Floc sweeping in floc filter*

**Floc filter:** slurry of suspended flocs in clarifier
**Floc sweeping:** removal of primary particles as they pass through flocs

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**Clarification Model: Spring 2024 and Summer 2024**

$$C_{clarified} = C_{flocculated} e^{-k_c \frac{C_{coagulant}}{C_{influent}} (1 - P_{floc\,saturated})^{2/3} h_{floc\,blanket}} \quad where\ k_C = k'\beta \frac{\pi r^2_{floc} C_{floc\,blanket}}{m_{floc}}$$

# Background & Introduction

## Clarification Model: Spring 2024 and Summer 2024

$$C_{clarified} = C_{flocculated} e^{-k_c \frac{C_{coagulant}}{C_{influent}} (1-P_{floc\ saturated})^{2/3} h_{floc\ blanket}} \quad where\ k_C = k'\beta \frac{\pi r^2_{floc} C_{floc\ blanket}}{m_{floc}}$$

Removal of primary particles by flocs in the floc filter

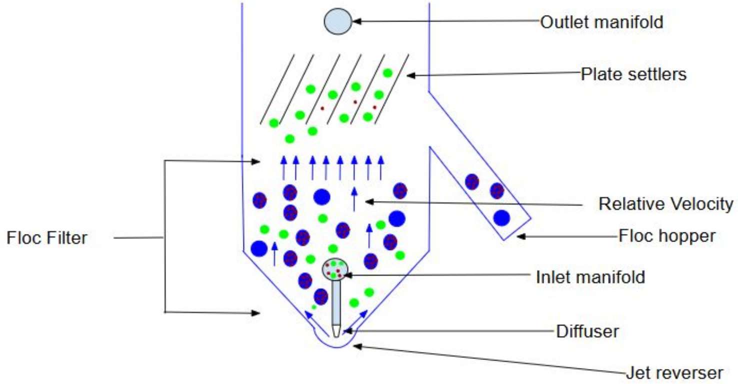


***Figure 3.*** *AguaClara clarifier*

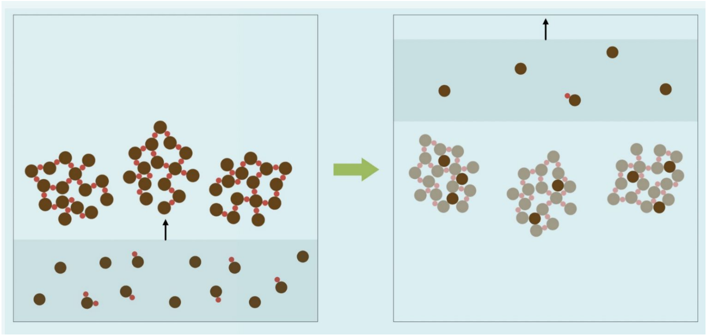

***Figure 4.*** *Floc sweeping in floc filter*

# Background & Introduction

**Floc Saturation:** the ratio of primary particles captured to the maximum number of particles a floc can capture

$$P_{floc\ saturated} = \frac{C_{flocculated} - C_{clarified}}{q(C_{influent} - C_{clarified})}$$

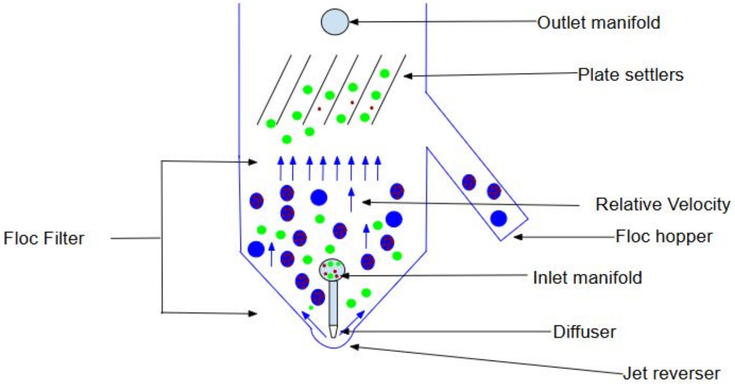


***Figure 3.*** *AguaClara clarifier*

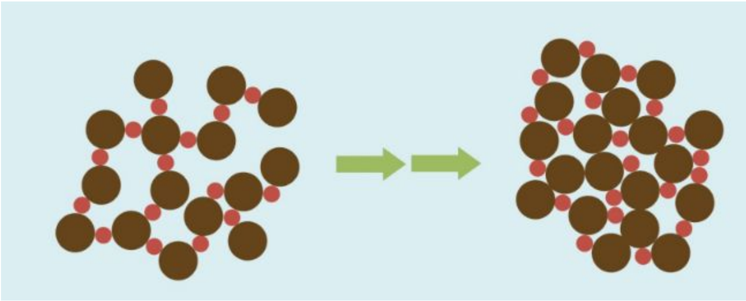

***Figure 5.*** *Floc saturation in floc filter*

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**What is the current problem?**

Clarification constant $K_c$ - fitted value (~60) and theoretical value (~0.06) do not match. Model underperforms clarification.

**What is missing?**

Model assumes a well-mixed floc filter with constant concentration and steady-state floc saturation. Does not fully account for <u>temporal or spatial variation</u> in floc filter concentration and floc saturation.

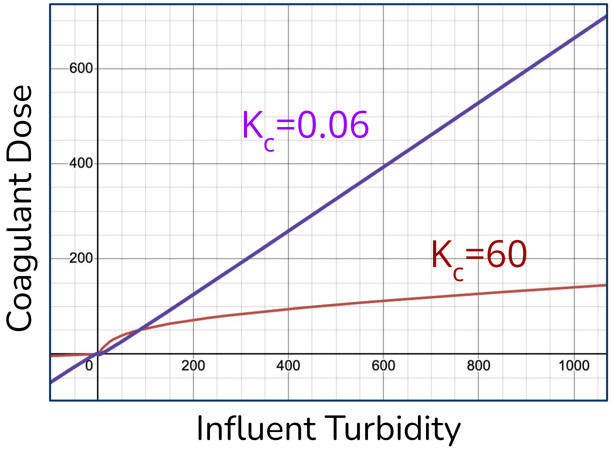


***Figure 6.*** *Significant difference between fitted and theoretical predictions of clarifier performance*

# Background & Introduction

## Floc saturation spatial variation - Hypotheses

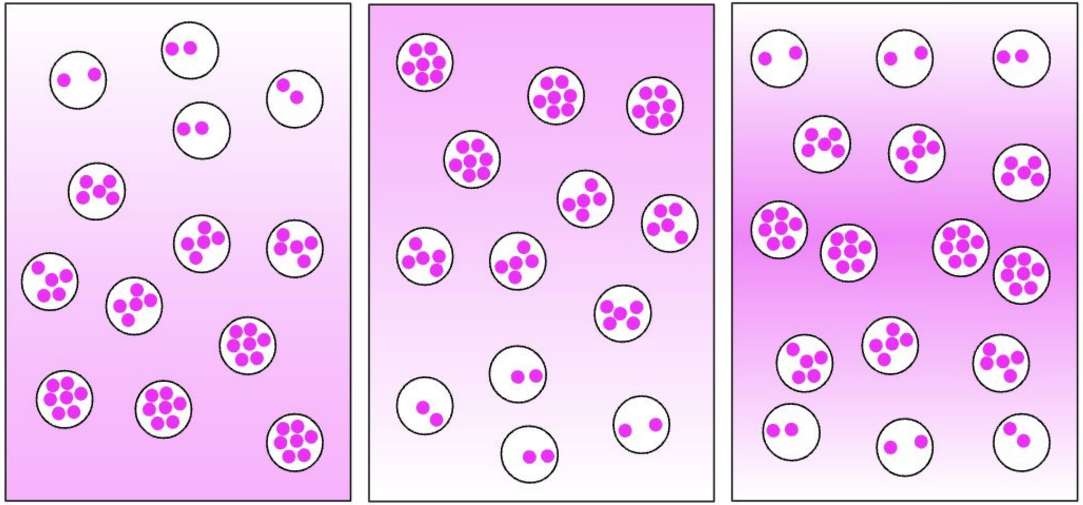

***Figure 7.*** *Spatial distribution of flocs in clarifier*

# Experimental Setup

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**Research objectives:**

1. Determine the spatial distribution of concentration and floc saturation in the floc filter
2. Correlate floc filter state with primary particle removal performance
3. Analyze how the above change temporally due to fluctuating influent turbidity and coagulant dose conditions

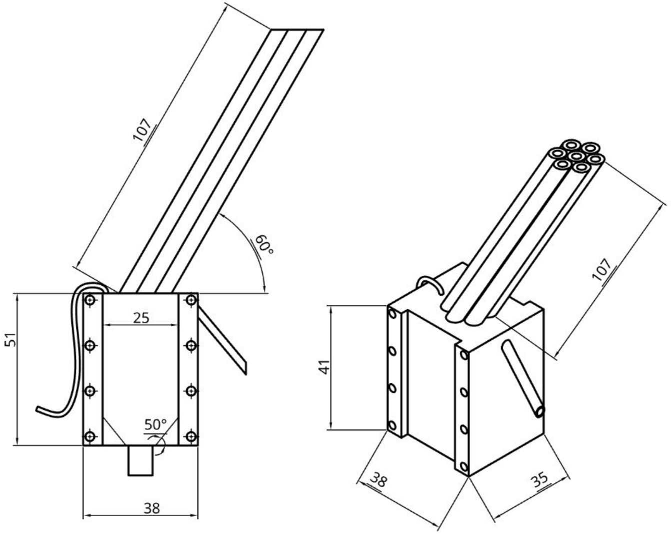
**Experimental apparatus criteria:**

- ❑ Short residence time
- ❑ Small, benchtop scale
- ❑ Modular, disassemblable
- ❑ Ability to measure floc filter concentration and floc saturation in situations.

# Methods

## Miniature Clarifier

Short residence time (<5 min), benchtop-scale
Acrylic, glass, metal, tubing, rubber; laser cut
First iteration: not modular




All measurements in mm and degrees

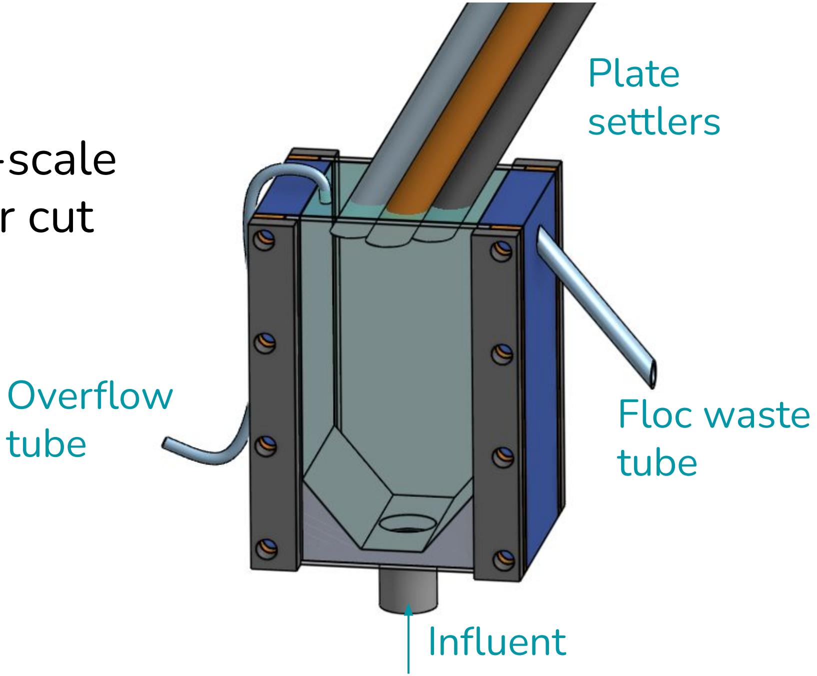



***Figure 8.** Miniature clarifier design and dimensions*

# Methods

### Visualization

Hurst et al., 2013
- Floc filter concentration and growth rate

Stream of colored primary particles
- Spatial variation in floc saturation

Reflected light (frontlit)

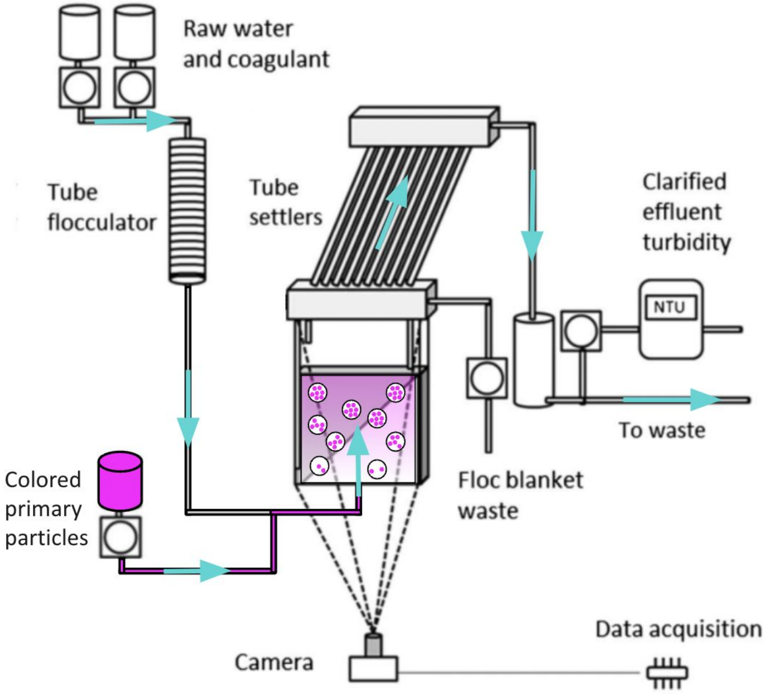



***Figure 9.*** *Experimental apparatus for imaging floc filter*

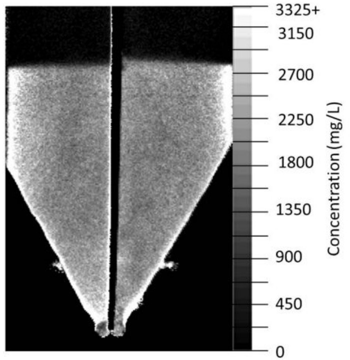



***Figure 10.*** *Imaging floc filter concentration (Hurst et al., 2013)*

# Current Work

### Jar Test - Experimental Design

1. Formed colored primary particles with rose kaolin clay
2. Formed flocs with white kaolin clay and coagulant
3. Divided primary particles into control and experimental
4. Added flocs to experimental to simulate floc sweeping in clarifier
5. Evaluated color after allowing flocs to settle

**Conclusion:** Rose kaolin primary particles are visibly dyed, but further testing needed to confirm dying of flocs

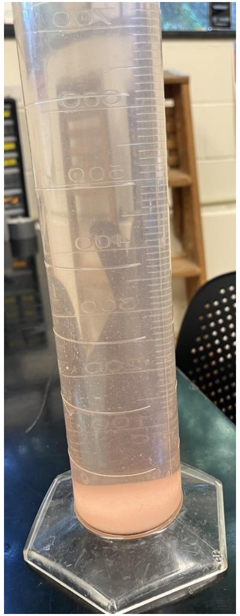


***Figure 11.*** *Colored Primary Particles After Floc Sweeping*

***Figure 12.*** *Colored Primary Particles (Frontlit)*

***Figure 13.*** *Colored Primary Particles (Backlit)*

# Broader Applications

- Exploring novel approach to visualize floc saturation
- Creating an easy-to-build and modular mini-clarifier to help future research
- Developing novel physical model of floc filter-based clarification
  - Understanding of floc filter dynamics → improved control over the state of the floc filter → more widespread use of floc filter-based treatment processes
  - Inform new clarifier designs

# Short Term Goals

- Purchase materials and build miniature clarifier
- Conduct experiments with miniature clarifier apparatus and interpret results
- Run more trials with colored primary particles
  - Red-40 dye
  - Reactive red & reactive yellow dye
  - Fluorescent latex beads

# Long Term Goals

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- Make the clarifier design more modular
- Improve the clarification model based on our results
- Move floc waste tube based on spatial distribution conclusions
- Apply findings to inform the work of the Plantita Subteam and Versawater
- Complete EPA P3 grant proposal

# References

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5. Hurst, M., Weber-Shirk, M., & Lion, L. W. (2014). Image analysis of floc blanket dynamics: Investigation of floc blanket thickening, growth, and Steady State. Journal of Environmental Engineering, 140(4). https://doi.org/10.1061/(asce)ee.1943-7870.0000817.
6. Hurst, M., Weber-Shirk, M., Charles P., & Lion, L. W. (2013). Apparatus for Observation and Analysis of Floc Blanket Formation and Performance. Journal of Environmental Engineering, 140(1). https://doi.org/10.1061/(ASCE)EE.1943-7870.0000773.

# Thank You!
# Questions?

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