# Automation of Chemical Dosing for Removing Dissolved Organic Matter From Drinking Water

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## Background

Dissolved organic matter (DOM), a naturally occurring transparent water contaminant, is found in unusually elevated concentrations at AguaClara's plant in Gracias, Honduras. When DOM reacts with coagulants like polyaluminum chloride (PACl), the contaminants clump together into flocs, which are more easily removed in the filtration process.

Achieving a relatively high density in flocs is crucial for the effective removal of DOM through flocculation. One method to achieve high density flocs is by using kaolin clay to simulate the turbidity of influent water and promote coagulation via collision aggregation. An alternative to kaolin clay is powdered activated carbon. Their porous surface has the capability to adsorb a large amount of dissolved organic matter onto its surface. This ability helps increase the effectiveness of the coagulant, reduce coagulant dosage, and create heavier flocs.

## Methods

```
#Calculations for upward velocity tests
Conc_PACl_System = 10 * u.milligram/u.L
Conc_HA_System = 10 * u.milligram/u.L

Conc_PACl_Stock = 131.34 * u.milligram/u.L
Conc_HA_Stock = 655.17 * u.milligram/u.L

Up_Velocity = 1 * u.millimeter/u.s #CHANGE THIS

Actual_Inner_Diameter_Sed_Tank = 26.6446 * u.millimeter
Actual_Area_Sed_Tank = ac.area_circle(Actual_Inner_Diameter_Sed_Tank)

Flow_Rate_Total = Up_Velocity * Actual_Area_Sed_Tank

Flow_Rate_PACl = Conc_PACl_System * Flow_Rate_Total / Conc_PACl_Stock * 0.001 * u.milliliter/u.millimeter ** 3
print("Flow Rate of PACl is", Flow_Rate_PACl)
Flow_Rate_HA = Conc_HA_System * Flow_Rate_Total / Conc_HA_Stock * 0.001 * u.milliliter/u.millimeter ** 3
print("Flow Rate of HA is", Flow_Rate_HA)
Flow_Rate_Water = Flow_Rate_Total - Flow_Rate_PACl - Flow_Rate_HA
print("Flow Rate of Water is", Flow_Rate_Water * 0.001 * u.milliliter/u.millimeter ** 3)
```

```
Flow Rate of PACl is 0.04245 milliliter / second
Flow Rate of HA is 0.00851 milliliter / second
Flow Rate of Water is 0.5066 milliliter / second
```

**Figure 1**. Deepnote code for calculating flow rates in the system. This code provides the capability to easily adjust system and stock concentrations, as well as upward velocities.

**Table 1**. Different States in ProCoDA with the Corresponding Flow Rates of Each Substance

| State name | Off | Iterate Clay | Run Water |
|---|---|---|---|
| Clay/PAC | Off | Iterate <50 rpm | Off |
| Water | Off | Iterate <50 rpm | 50 rpm |
| PACl | Off | Constant <50 rpm | Off |
| Humic Acid | Off | Constant <50 rpm | Off |
| Waste | Off | 50 rpm | 50 rpm |

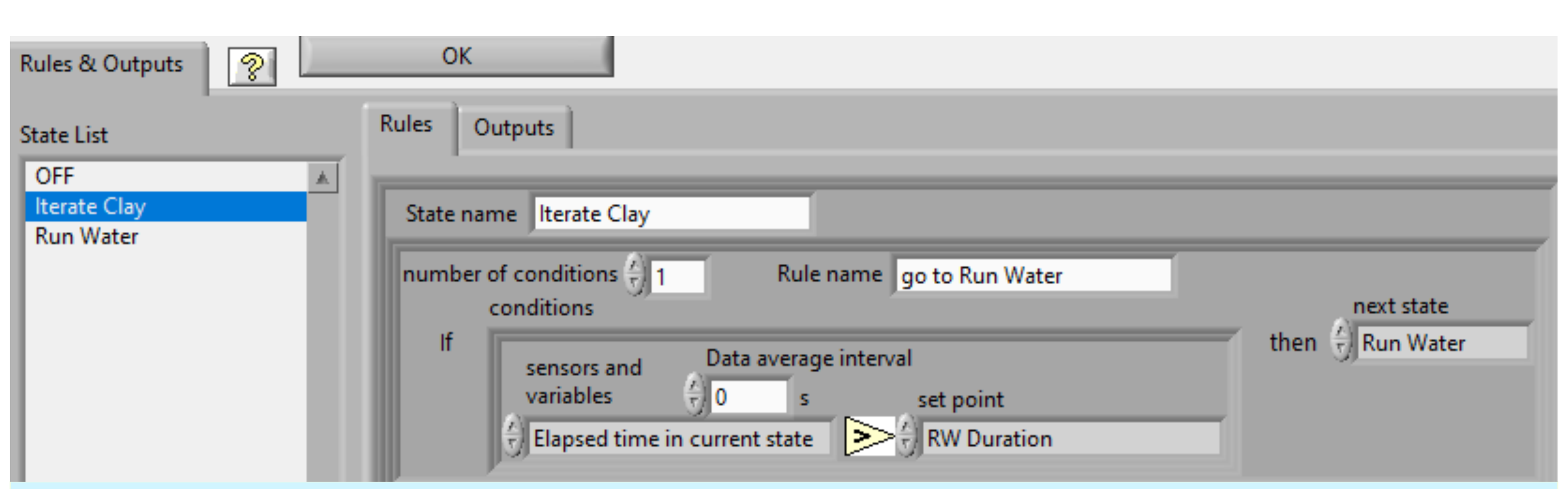


**Figure 2**. The *Iterate Clay* state with its conditions and rules on ProCoDA.

## Experimental Apparatus

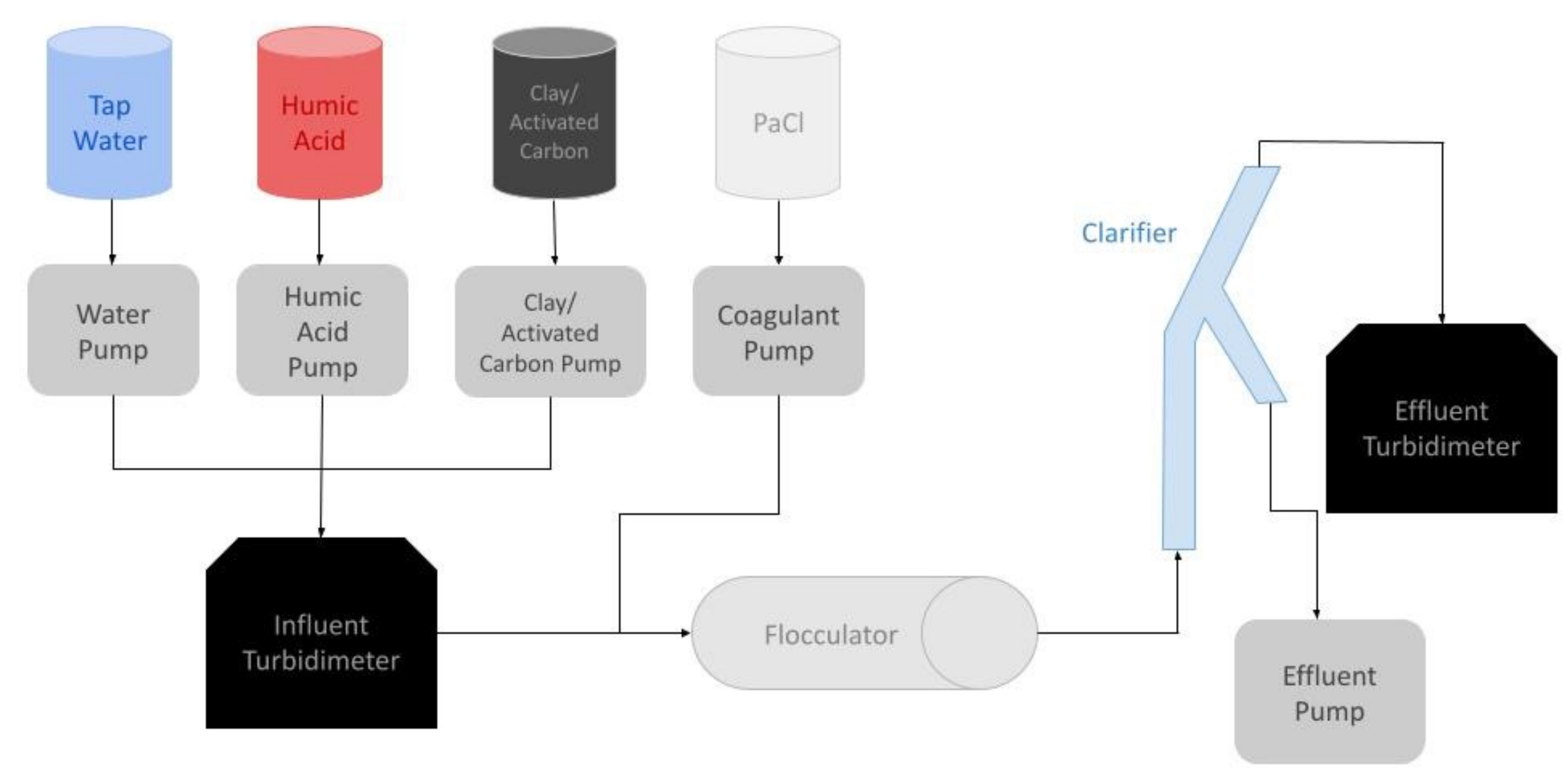


**Figure 3**. Schematic drawing of the experimental setup for testing varying clay and activated carbon concentrations.

## Results

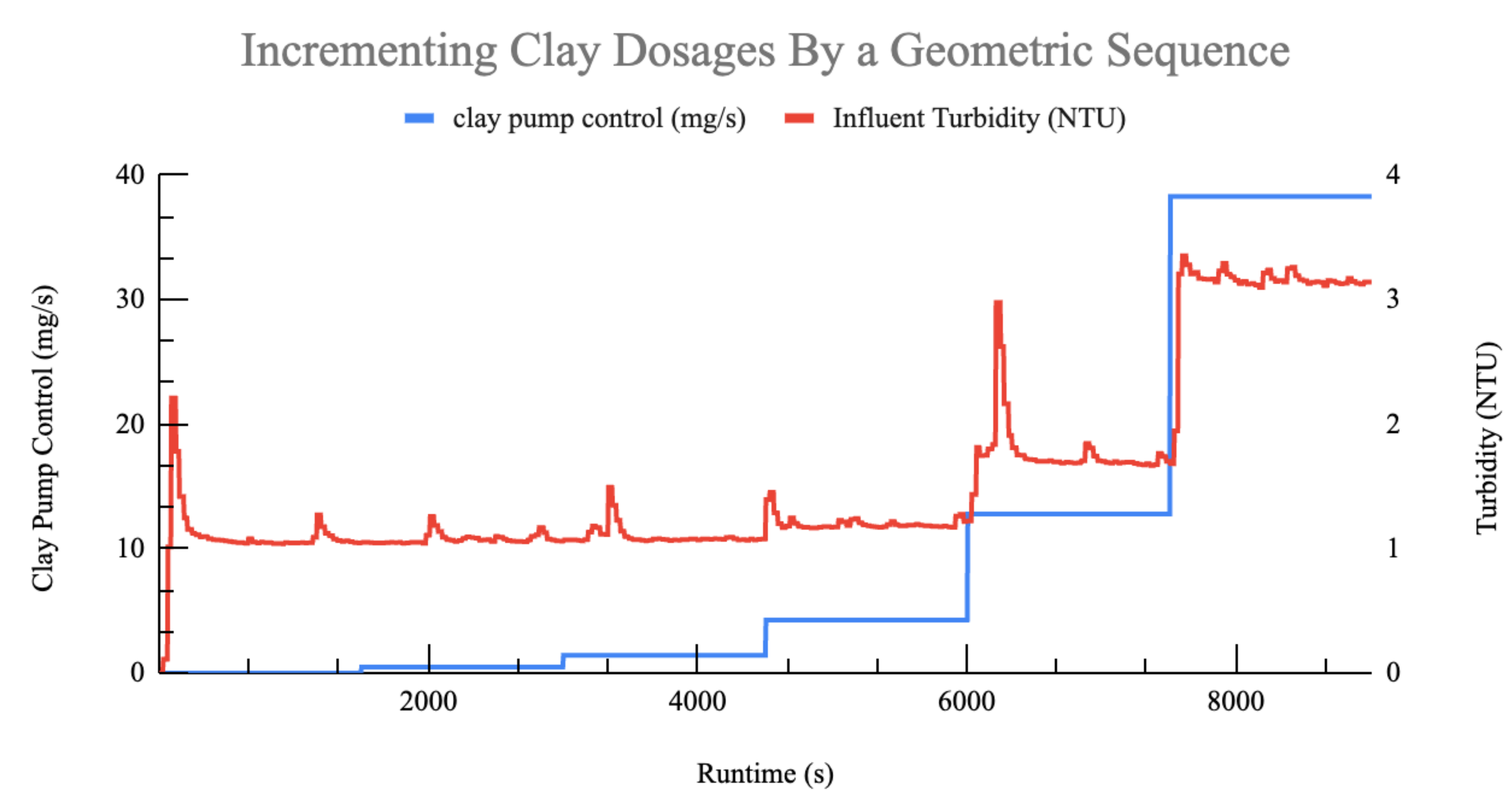


**Figure 4**. Graph illustrating the relationship between turbidity and time, with varying clay dosages using a geometric series. Automation of the flow rates and data collection were conducted using ProCoDA.

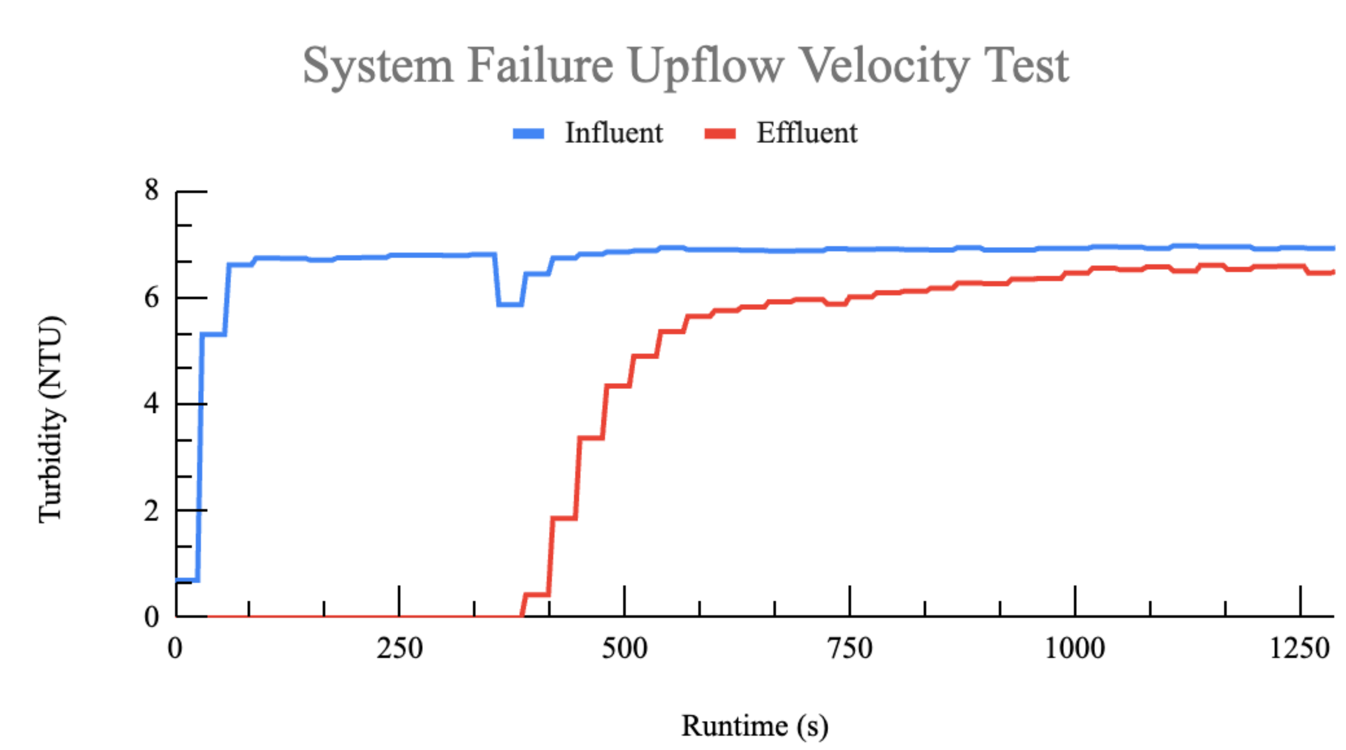


**Figure 5**. Graph demonstrating the system approaching failure with only coagulant (PACl) and humic acid (DOM) at 3.35 mm/s upflow velocity. The flow rates employed in the system were computed utilizing the Deepnote file that was depicted in Figure 1. Automation of the flow rates and data collection were conducted using ProCoDA.

## Analysis

In Figure 4, geometric clay dosage incrementations were used to demonstrate its direct correlation with the elevation of influent turbidity. The higher dosage of clay particles contributes to the influent water becoming 'cloudier,' thereby elevating turbidity levels. Moreover, the upflow velocity also contributes to changes in turbidity. In Figure 5, an upflow velocity of 3.35 mm/s generates an upward force within the water, hindering the sedimentation of flocs. This interference in the settling process is crucial, as it leads to the ultimate failure of the system where the effluent turbidity closely approaches the influent turbidity.

## Conclusions

Geometric clay dosage incrementations were successfully automated with ProCoDA, which manages the dispensation of various dosages at specified time intervals. Utilizing ProCoDA to conduct trials instead of manually preparing new dilutions of solutions is significantly more time-efficient. This efficiency enables the collection of a greater amount of data on various clay dosages within the same timeframe as previous runs. Furthermore, the conditions for system failure have been identified, notably an upflow velocity of approximately 3.35 mm/s. This provides a foundation for a model of the flocculation issue in the Gracias plant.

## Future Work

Our next steps involve conducting experiments where we incrementally add clay in an arithmetic progression, following the conditions outlined in Figure 1. The ProCoDA code utilized for running these experiments will closely resemble the one employed for incrementing clay dosages in a geometric series, while maintaining a consistent upflow velocity of 3.35 mm/s. Following this, we plan to replicate the process, substituting clay with activated carbon. We will perform a comparative analysis to assess performance variations and explore the financial trade-offs associated with each material.

## References

Tafvizi, H., Chowdhury, S., & Husain, T. (2021). Low cost activated carbon for removal of NOM and dbps: Optimization and comparison. *Water*, 13(16), 2244. https://doi.org/10.3390/w13162244

Wu, Z., Zhang, X., Pang, J., Zhang, X., Li, J., Li, J., & Zhang, P. (2020). Humic acid removal from water with pac-al30: Effect of calcium and kaolin and the Action Mechanisms. *ACS Omega*, 5(27), 16413–16420. https://doi.org/10.1021/acsomega.0c00532