Tube Flocculator

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Abstract

We lack a fundamental understanding of the flocculation process. Even relatively simple concepts such as "sticky" are poorly understood. The overarching goals of the tube flocculator research are to develop a fundamental understanding of the flocculation process and to optimize flocculator design in AguaClara facilities.

students	3
skills	fabrication, some fluid mechanics

1 Introduction

The design of water treatment plants has not been optimized for reduction of water waste, minimization of chemical use, or minimization of overall carbon and ecological footprint. The design algorithms that have been generated as part of the AguaClara Design Tool facilitate the analysis of construction costs for a given design. The more complex optimization involves changing key expert input parameters. The goal of research with the tube flocculator apparatus is to develop flocculation models that make it possible to characterize the influence of flocculator parameters on the overall operation of an AguaClara plant. The flocculation models should be based on the fundamental physics of the flocculation process and should characterize both floc fragment generation from floc breakup and floc aggregation.

2 FReTA - Tube Flocculator Research

The overarching goal of the Tube Flocculator Research is to assess the requirements for successful flocculation. Successful flocculation will be defined differently depending on which operations follow it. Subsequent operations could be almost any combinations of floc blanket/plate settlers/filtration. The two key parameters describing the output of the flocculator are the mean floc size and the residual turbidity measured at a particular sedimentation velocity. Both of these parameters may be important. If a floc blanket is used, then the flocculator must produce flocs that settle in the sedimentation tank. Given the presence of plate settlers, then it should be easy for the flocculator to produce flocs that can be captured by the plate settlers and returned to the sedimentation tank to form a floc blanket. The residual turbidity after flocculation may influence the final turbidity after the last unit operation or it is possible that subsequent unit operations are more efficient at lowering residual turbidity. It is very likely that it will be possible to reduce the size of flocculators after floc blankets and filters have been added to the AguaClara treatment train.

There are multiple objectives for flocculation research.

1. Develop a fundamental understanding of the mechanisms by which coagulants enhance particle aggregation. This fundamental understanding should have predictive capabilities including coagulant dosages as a function of suspended solids concentration.

Hypotheses

It would be great to be able to create models to describe these interactions.

1. The lower residual turbidity with increased coagulant dose is due primarily to improved attachment efficiency. The lack of any improvement at very low dosages is because the attachment efficiency is so poor that no flocs grow large enough to have a sedimentation velocity greater than the capture velocity.

2. The lower residual turbidity with increased collision potential is due to increased number of successful collisions.

3. For a given target residual turbidity the coagulant dose can be decreased by increasing the collision potential

4. The residual turbidity is the result of a lack of successful collisions for small products of collision potential, ψ, and attachment efficiency, α, and is due to floc breakup for large products of $\alpha\psi$.

5. The residual turbidity for large values of $\alpha\psi$ increases with the energy dissipation rate, ϵ.This is one of the reasons why floc blankets help improve performance. The low energy dissipation rate in the floc blanket allows flocs to grow larger and the production of floc fragments that are smaller than the capture velocity, V_C, of the plate settlers is reduced. The probability that a floc fragment has a sedimentation velocity that is less than V_C is a function of the floc size. Small flocs will frequently shed fragments that are below the V_C and large flocs will rarely shed fragments that are below the V_C.

6. Floc attachment efficiency is a function of the magnitude of electrostatic repulsion and polar bond attraction. A monolayer of aluminum hydroxide or PACl is sufficient to create a strong bond between flocs. The electrostatic repulsion can be decreased by either burying the particle surface

charge with a layer of coagulant or by charge neutralization by adsorbed cations? Is there some mechanism for the coagulant precipitate to have a positive charge? I think the answer is yes... PZC. Is flocculation possible at the point of zero charge of PACl?

Reflections

1. The inability of PACl to flocculate at low pH suggests that absorbtion of PACl cations is not sufficient to cause successful bonding between clay particles. If charge neutralization is an important mechanism, then the most efficient flocculation should occur at pH with a high dissolved PACl concentration. The correlation of good flocculation at low dissolved PACl concentrations (near neutral pH) suggests that the highly charged dissolved coagulants are ineffective.
2. The effect of ionic strength on the Debye layer thickness perhaps could be used to assess if the mechanism for improved attachment efficiency is charge neutralization or charge burial.
3. If the coagulant is precipitating, then doesn't that mean that the mechanisms for enhancing attachment efficiency isn't neutralizing the charge? Isn't the zero charge of the solid form inconsistent with the charge neutralization hypothesis?
4. Is there a way to characterize the charge density of precipitated PACl? I believe the granular PACl is very electrostatic. Is this related to its charge density?

3 Overview of Optimization Parameters (inputs)

3.1 Flocculator

3.1.1 Collision potential

3.1.2 Energy dissipation rate

3.2 Sedimentation Tank

3.2.1 Upflow velocity in the bottom of the sedimentation tank

3.2.2 Floc blanket depth

3.2.3 Plate settler capture velocity

3.2.4 Floc hopper

The output of the flocculator/sedimentation tank processes is clarified water with low residual turbidity and wastewater with highly concentrated solids.

3.3 Filter

The clarified water from the sedimetation tank becomes the input to the filter.

3.3.1 Filter layer depth

3.3.2 Sand grain diameter

3.3.3 Filtration velocity

The output of the filter is very clean water and backwash water. The amount of backwash water is directly related to the turbidity of the input water. The backwash water does not have as high a level of suspended solids as the sludge produced by the sedimentation tanks. Water waste (backwash water) is minimized by reducing the turbidity of the water leaving the sedimentation tanks.