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2004 EPA STAR Graduate Fellowship Conference — Next Generation Scientists—Next Opportunities

Simultaneous Precipitation and Flocculation in Water Treatment: Modeling and Experiments

Problem Statement

Tightening regulations and the increasing use of non-traditional downstream treatment processes are changing the role of flocculation in drinking water treatment. The current understanding of precipitative coagulation, which is employed by the vast majority of treatment plants, is not sufficient to allow water treatment engineers to meet these challenges.

Background/Motivation

Flocculation is the process of inducing particle collisions and growth by providing detention time and mixing. The aim is to convert the large number of small particles that are present in the raw water into a smaller number of large particles that are easily removed in subsequent processes.
Precipitative Coagulation refers to flocculation processes where new solids are formed from added chemicals (*e.g.*, alum or iron sweep-floc coagulation and lime softening).

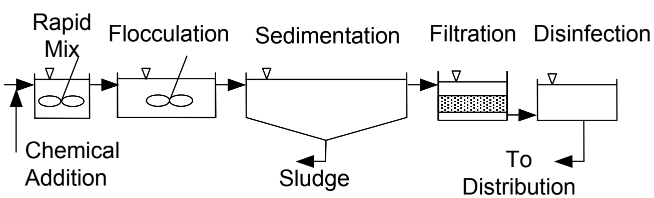


Figure 1. Conventional Water Treatment Plant

Mathematical Modeling of Flocculation:

Long-Range Model – accounts for collisions caused by long-range transport mechanisms of Brownian motion, fluid shear, and differential sedimentation
Short-Range Model – includes short-range van der Waals attraction and hydrodynamic interactions between particles

- Presently, successful modeling of time-varying particle size distributions (PSDs) during flocculation is limited to cases in which no new solids are formed (Figure 2A, Short-Range).
- Comparison of experimental data and modeling results from lime softening experiments show that the model in its current form is woefully inadequate for describing simultaneous precipitation and flocculation (Figure 2B).

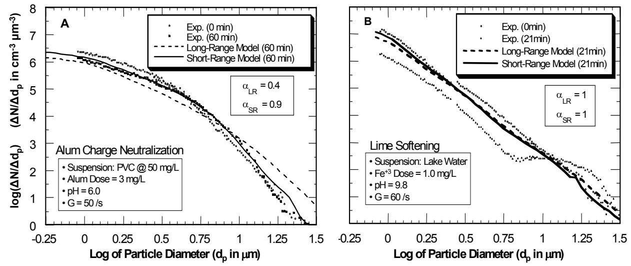


Figure 2. Flocculation Modeling: A. Success and B. Failure

New Roles for Flocculation:

- New regulations for the removal of particles and dissolved constituents such as arsenic and NOM have placed an increased focus on precipitative coagulation processes.
- The optimal PSDs required by new downstream processes (*e.g.*, dissolved air flotation and membrane filtration) can be quite different from those required by conventional treatment (sedimentation and granular media filtration).

Research Methodology

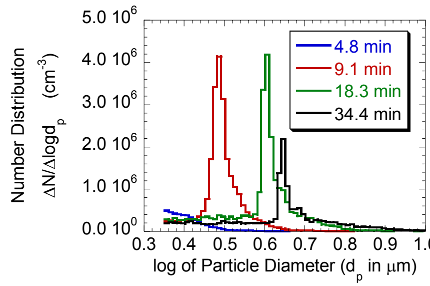
Objective:

Develop a mathematical model that quantitatively describes how PSDs are changed by simultaneous precipitation and flocculation

Approach:

Mathematical modeling – incorporate precipitation (nucleation and crystal growth) into the existing short-range flocculation model
Laboratory experimentation – 1) determine rate expressions for nucleation and crystal growth; 2) measure the evolution of PSDs in precipitative coagulation processes

- Batch precipitation experiments
  - $CaCO_3$ to emulate lime softening
  - $Al(OH)_3$ to emulate alum sweep coagulation
- PSD measurements via Coulter Counter (see Figure 3)



- Batch
- Unseeded
- Synthetic Lake Austin, TX water
- pH: 9.8
- Lime Dose: 9.3 mg/L as CaO

Figure 3. PSD Evolution During Lime Softening

Synthesis – calibrate and verify model with experimental PSD data from independent experiments

Potential Impacts

Improved Drinking Water Quality:

The model produced as a result of this research will be used as a tool to help water treatment engineers optimize precipitative coagulation; the new roles of these processes must be considered in design and operation. Such optimization will likely result in cleaner, safer drinking water.

This fellow is sponsored by EPA's STAR or Greater Research Opportunities (GRO) Program.