Coagulant/Polymer 101: Fundamentals of Thickening and Dewatering

Yong Kim, Ph.D.
UGSI Solutions, Inc.
Vineland, NJ

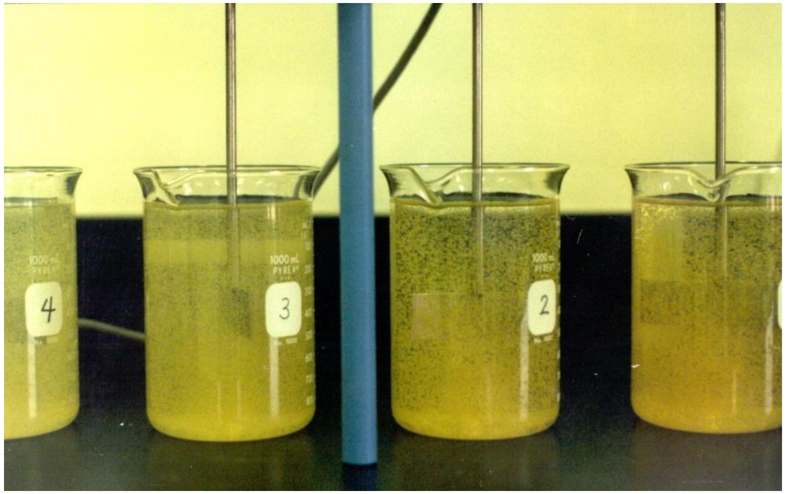
NEWEA 2023 Annual Conference
Boston, MA, 1/22 – 1/25

UGSI Solutions

Presentation Overview

1. Basic Chemistry
   - Coagulation and Flocculation
   - Molecular weight, Active content, Polymer type and size
   - Handling and storage
   - Viscosity of polymer solution
2. Science of Polymer Activation
   - Effect of make-up or dilution water
   - Two-stage mixing
   - Residence time of mix chamber
3. Case Studies
   - Neshaminy Water Treatment Plant, Oakford, PA
   - F. Wayne Hill WRC, Gwinnett County, GA
4. Summary

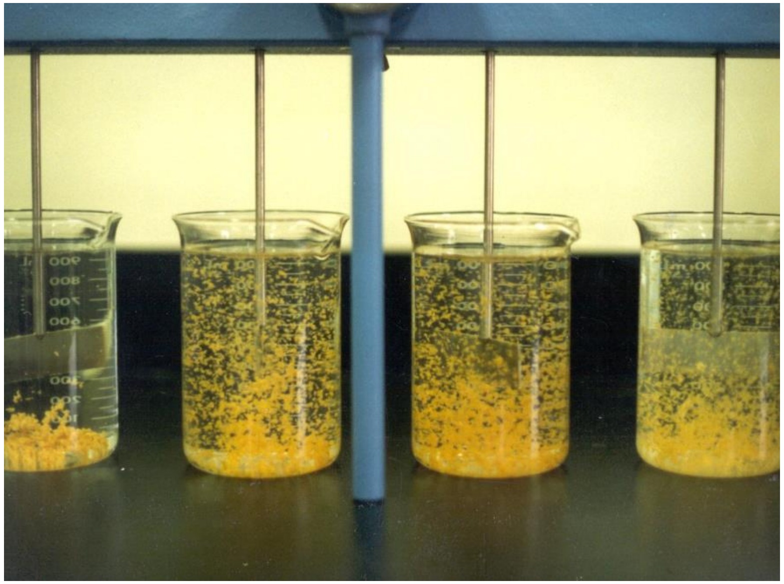
Coagulation and Flocculation



Coagulation

- Double-layer compression (charge neutralization)
- Enmeshment (sweep coagulation)

- Clay suspension + Ferric chloride (40 - 120 ppm)



Flocculation

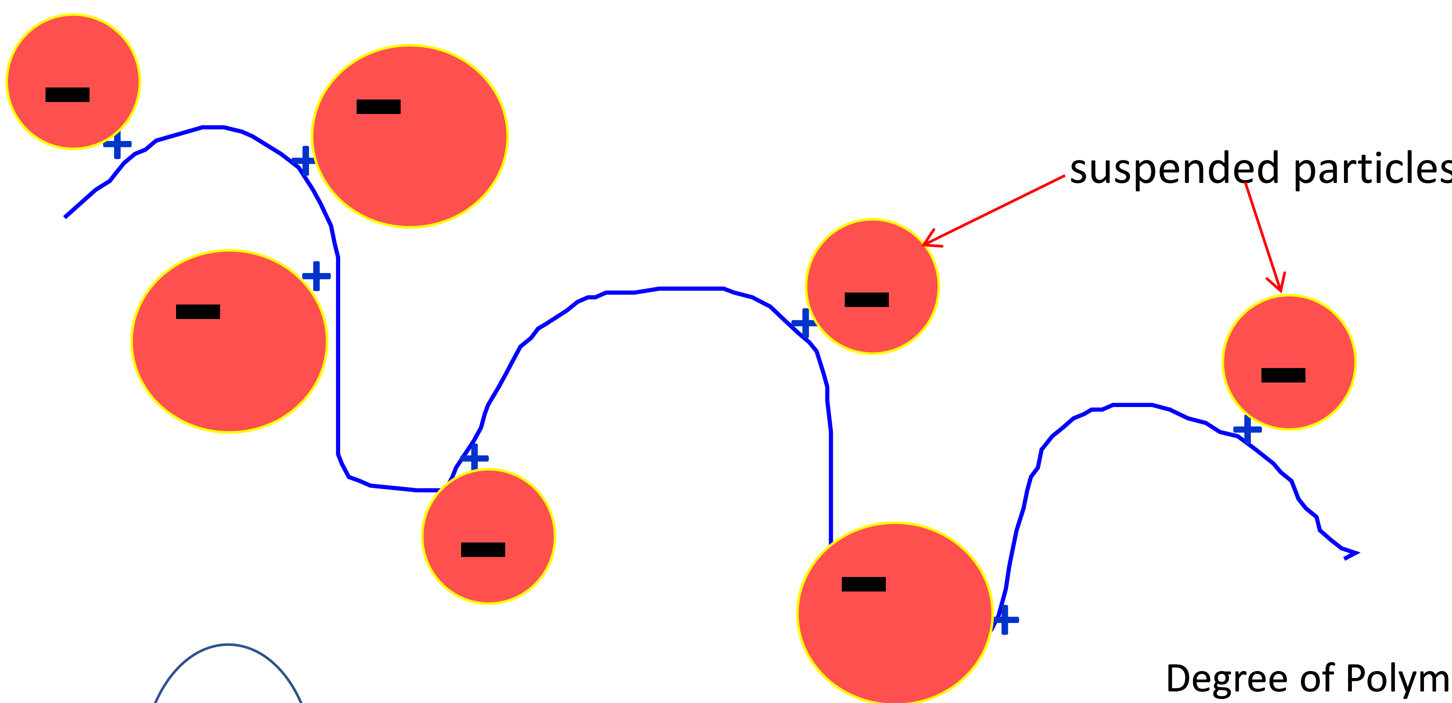
- Polymer Bridging

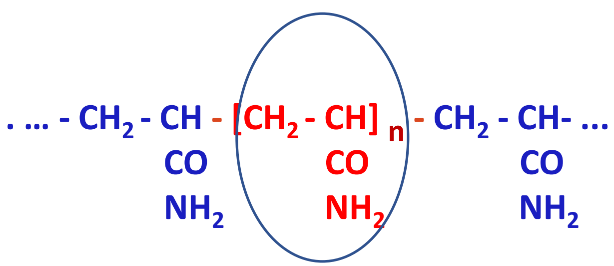
- Clay suspension + Ferric chloride + Polymer (< 1 ppm)

UGSI Solutions

Flocculation - Bridging by Long-chain Polymer Molecules

Extended <u>cationic</u> polymer molecule attracts negatively-charged particles.





Acrylamide
(monomer)

Degree of Polymerization
(No. of monomers to make one polymer molecule)

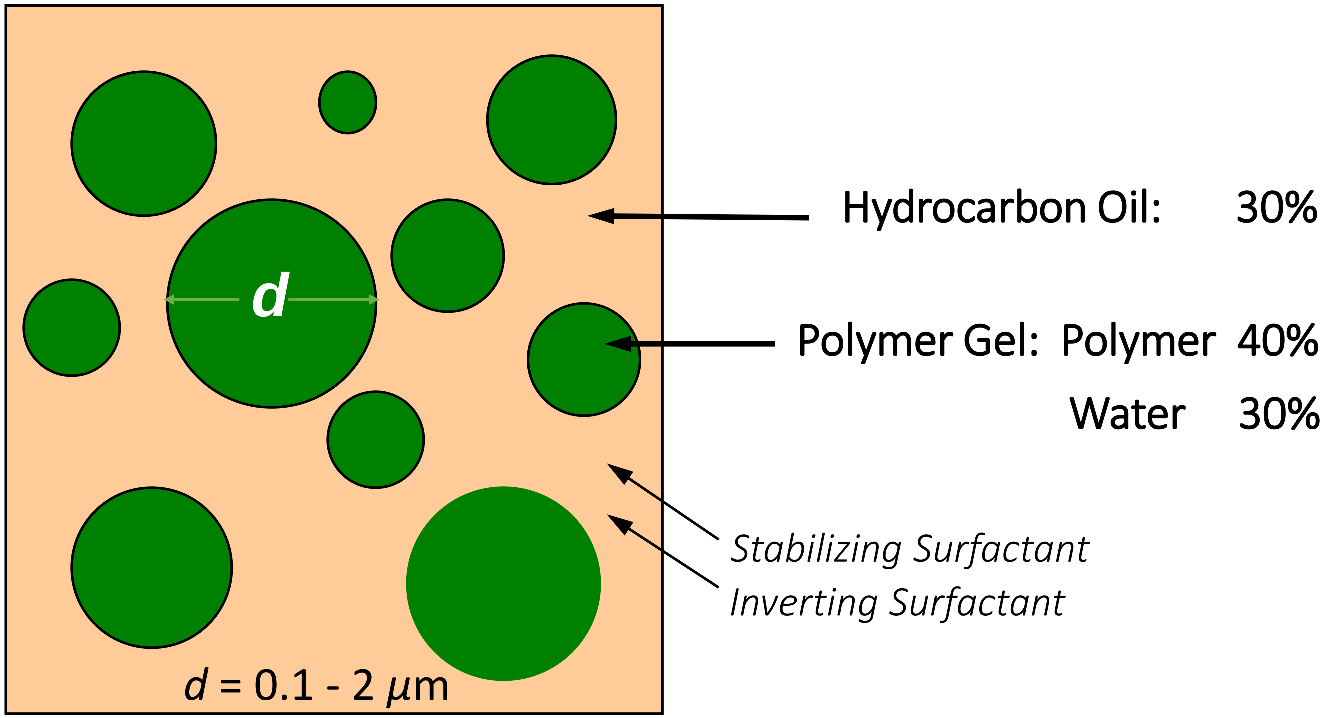
Polyacrylamide (PAM)

For 10 million MW polymer, **n** = <u>**140,000**</u>

(10,000,000 / 71)

UGSI Solutions

Configuration of Emulsion Polymer (40% active)



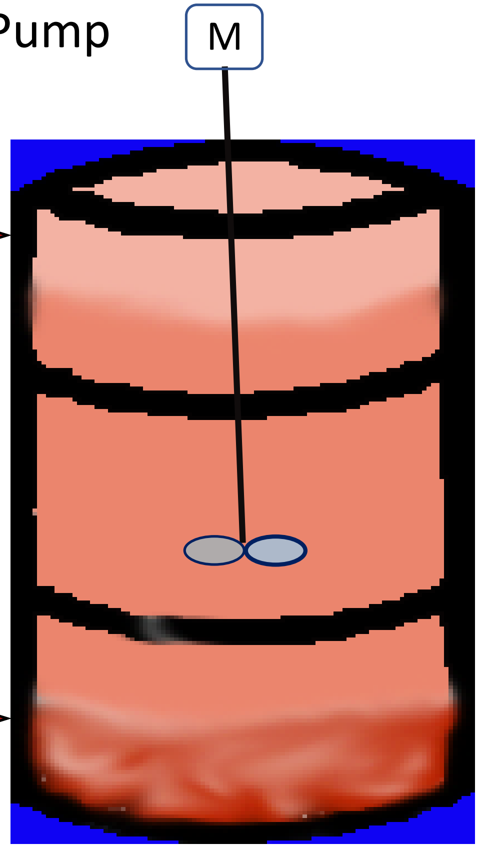
Dry polymer particles: 0.1 - 2 *m*m

<u>Specific gravity</u> difference between hydrocarbon oil and polymer gels

UGSI Solutions

Storage of Emulsion Polymer

- Separation (stratification)
  - * Drum (Tote) Mixer
  - * Recirculation Pump



Separated Oil

Settled Out
Polymer Gels

- Moisture Intrusion
  - * Drum (Tank) Dryer

UGSI Solutions

Handling & Storage

Shelf Life:

- Emulsion: 6 months, un-opened drum/tote
- Dry: up to 3 years, un-opened bag
- Polymer solution: depends on concentration, water quality

Storage Temperature: 40 F - 90 F

- Do not allow emulsion to freeze
- Once frozen, thaw in heated area and mix well

Handling

- Wear latex gloves and eye protection
- Minimize exposing to air, avoid dusting (dry polymer)
- Don’t try to clean spilled polymer with water
    - Use absorbents (vermiculite, sawdust, paper towel)
- Always consult SDS

Physical Forms of HMW Polymers

Dry Polymer

- Cationic, anionic, non-ionic
- Molecular weight: up to 10 M (cationic), up to 20 M (anionic, non-ionic)
- up to 90% active
- Polymer particle size: <u>0.1 - 2 mm</u>

Emulsion Polymer

- Cationic, anionic, non-ionic
- Molecular weight: up to 10 M (cationic), up to 20 M (anionic, non-ionic)
- 30 - 60% active (40% most common)
- Polymer gel size: <u>0.1 - 2 μm</u>

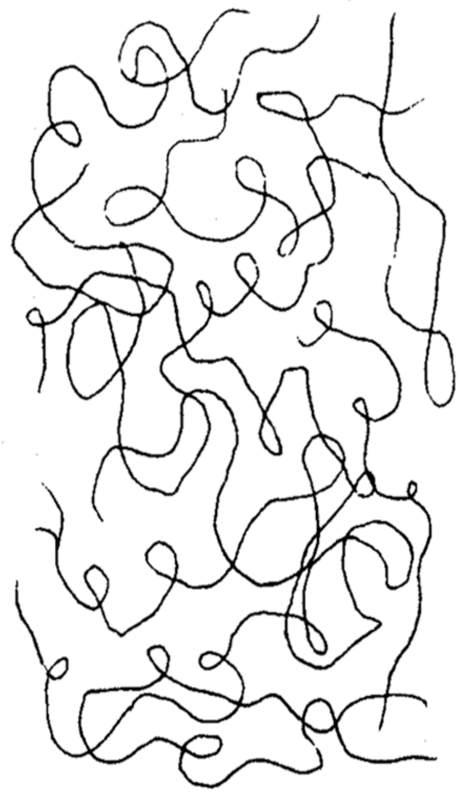
Solution Polymer (Mannich)

- Cationic only
- Molecular weight: up to 10 M
- 4 - 6% active
- Limited usage

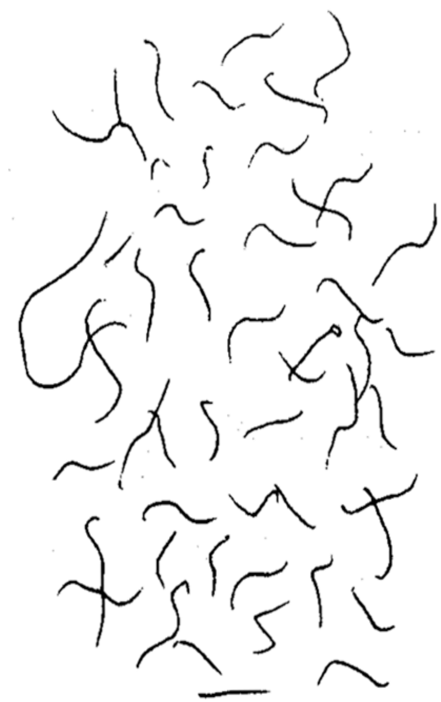
Three Forms of Polymer Solutions

Neat polymer

(A) Fisheyes due to poor initial wetting



(B) Ideal polymer chains by two-stage mixing

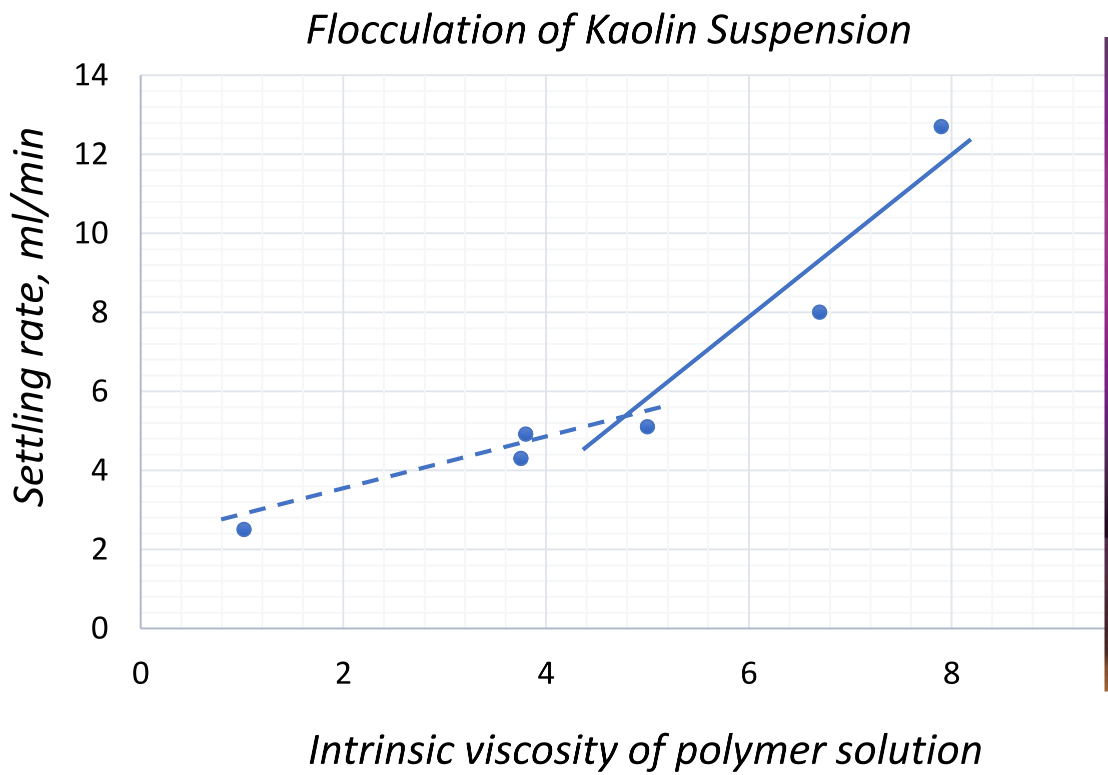


(C) Broken polymer chains by conventional batch mixing

Viscosity – Indicator of Polymer Solution Efficiency

Viscosity of Polymer Solution and Settling Rate

Higher Viscosities Accelerate Settling Rate



Sakaguchi, K.; Nagase, K., Bull. Chem. Soc. Japan, 39, p.88 (1966)

UGSI Solutions

Effect of Dilution Water Quality

Polymer supplier data sheet provides a starting point for viscosity critical factor for polymer efficiency

Solenis, Inc.

Table of Properties - PRAESTOL® Cationic Polymers (Emulsion)

PRAESTOL POLYMER GRADE	CATIONIC CHARGE	ACTIVE CONTENT	DENSITY (GR/ML)	PRODUCT VISCOSITY (CP)	SOLUTION VISCOSITY 1% IN DIST. WATER[1] (CP)	SOLUTION VISOCITY 1.0% in 10% NaCl-Brine [2] (CP)	FREEZING POINT (°C)	EFFECTIVE pH RANGE
K105L	Low	30%	1.04	<4000	>5000	>2000	-15	1-10
K110FL	Low	35%	1.03	<4000	>3000	>1000	-15	1-10
K120L	Low-Medium	40%	1.03	<4000	>7000	>500	-15	1-10
K226FLX	Medium	29%	1.03	<4500	>8000	>400	-15	1-10
K111L	Medium	40%	1.03	<4000	>7000	>500	-15	1-10
K122L	High	43%	1.04	<4000	>9000	>300	-15	1-10
K128L	High	43%	1.04	<4500	>9000	>900	-15	1-10
K132L	High	35%	1.01	<5500	>8000	>300	-15	1-10
K133L	High	44%	1.05	<4000	>8000	>150	-15	1-13

Effect of Dilution Water on Polymer Activation

Ionic strength (Hardness): multi-valent ion hinders polymer activation

- Soft water helps polymer molecules fully-extend faster
- Hardness over 400 ppm may need softener

Oxidizer (chlorine): chlorine attacks/breaks polymer chains

- Should be less than 3 - 4 ppm
- Caution in using reclaimed water for polymer mixing
    - Negative impact on aging (maturing)

Temperature*: higher temperature, better polymer activation

- Water below 40 ºF may need water heater
- Water over 100 ºF may damage polymer chains

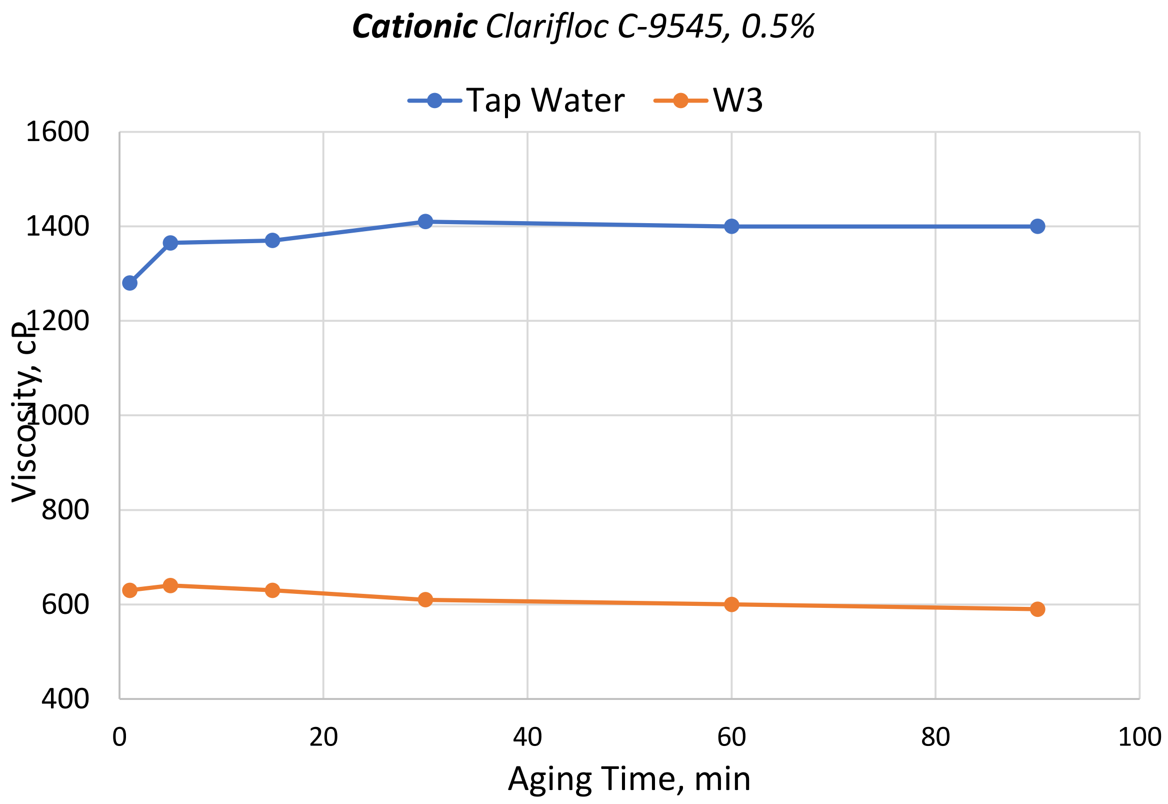
Suspended Solids/ Turbidity/ TDS:

- In-line strainer recommended
- Caution in using reclaimed water for polymer mixing

UGSI Solutions

Use of Tap Water vs Reclaimed Water

Polymer solution in 600 mL beakers, 500 rpm for 20 min
W3 from Landis Sewerage Authority, Vineland, NJ



- Viscosity of polymer solution with reclaimed water: significantly lower
- Polymer solution with reclaimed water: degraded over aging

Polymer Activation (Mixing, Dissolution)

(I) Initial Wetting (Inversion)

Sticky layer formed

High-energy mixing -> No fisheyes

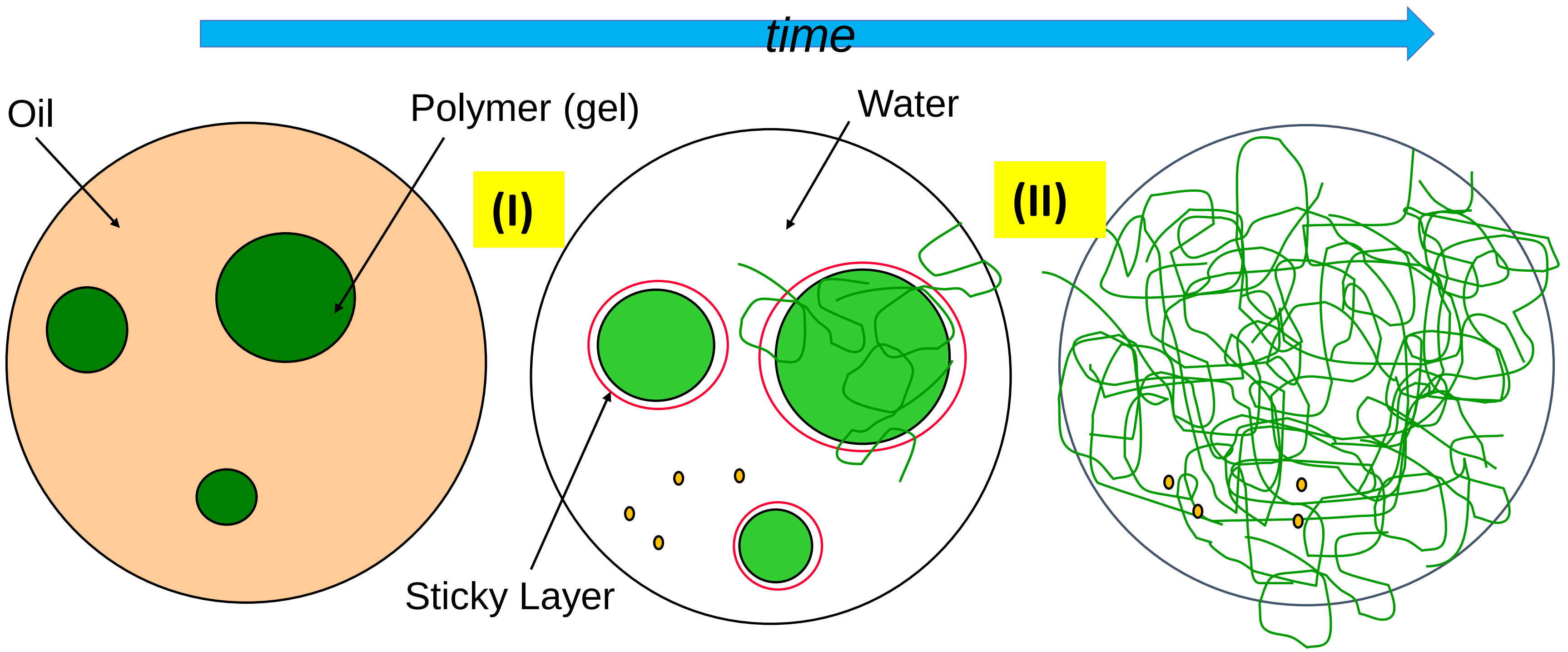
Most Critical Stage - Brief

(II) Dissolution

Reptation* or Uncoiling

Low-energy mixing -> No damage to polymer

Longer Residence Time required

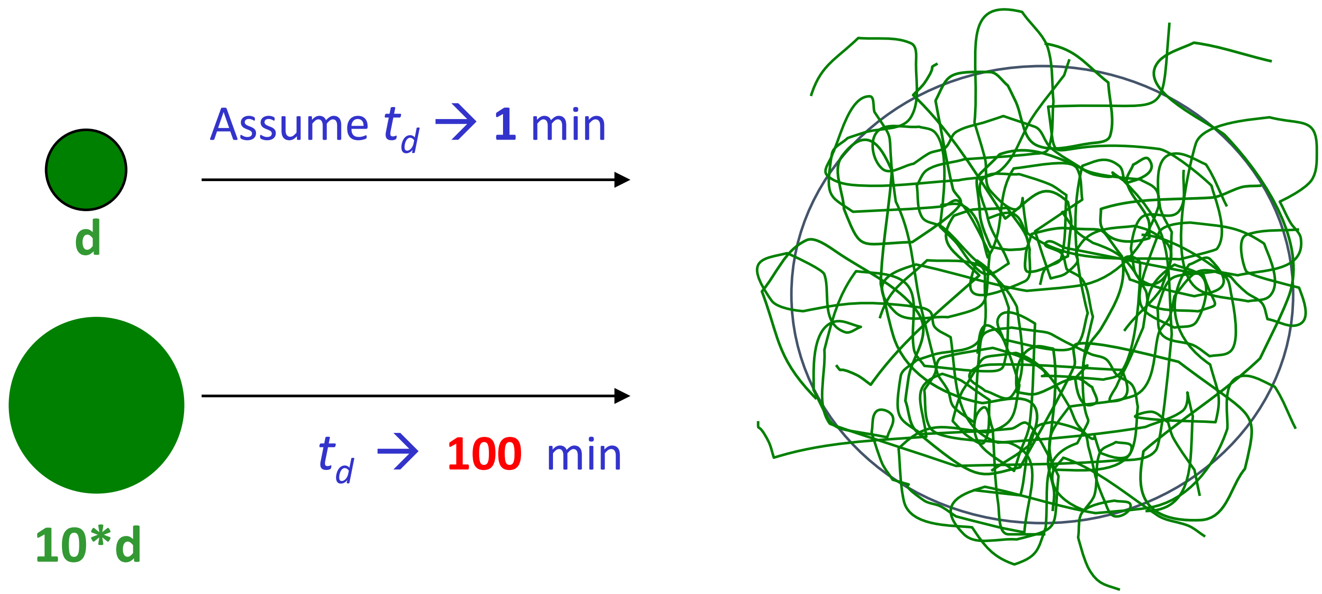


* de Gennes, P.G., J. Chem. Phys., 55, 572 (1971)

UGSI Solutions

Why Initial High-Energy Mixing is So Critical?

Polymer dissolution time, $t_d \sim (\text{diameter})^2$ *Tanaka (1979)**



Initial high-energy mixing → No fisheye formation → Shorter mixing time

* Tanaka, T., Fillmore, D.J., *J. Chem. Phys.*, 70 (3), 1214 (1979)

(1) **Two-Stage Mixing** in mix chamber

higher energy mixing → low energy mixing

SNF POLYDYNE   SOLENIS

There are a number of commercially available automatic feed systems that provide in-line mechanical mixing. The best units of this type feature initial high energy mixing (>1000 rpm) for a short time (<15 sec) to achieve good dispersion of the product into water. This is followed by lower energy mixing (<400 rpm) for a longer period of time (10-20 min) and aging for an additional 10-20 minutes to achieve complete polymer dissolution. Best practice is to use these in-line dilution systems followed by a mixing/aging tank fitted with high/low level probes to refill the tank. The optimum concentration in the mixing/aging tank is 0.5 percent, and in no case should the initial concentration of polymer be less than 0.25 percent for best results.

Mixing Effect on Polymer Activation

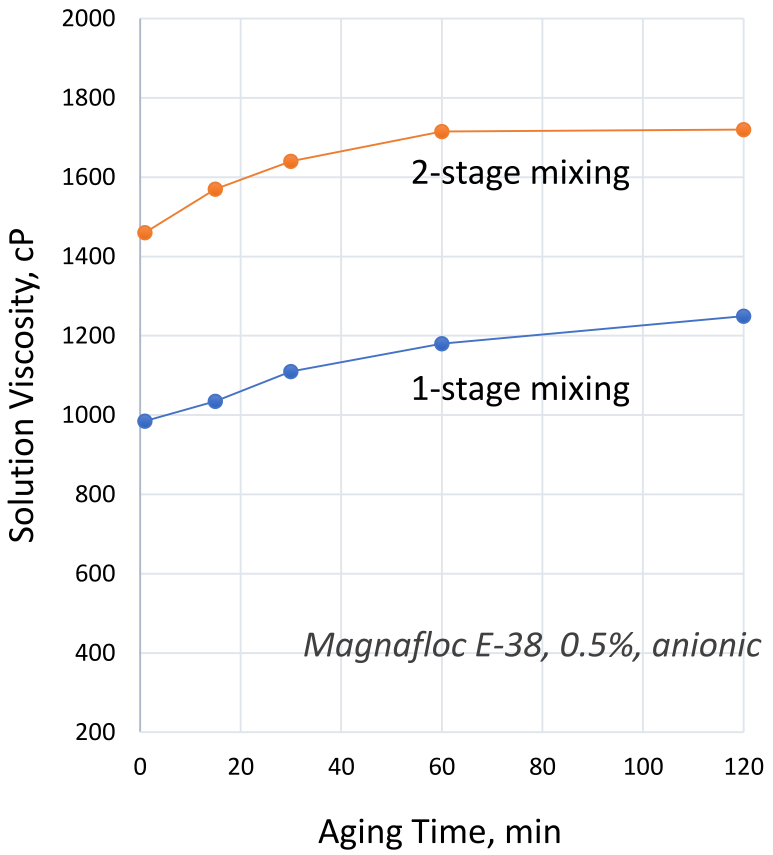
Very HMW anionic polymer solution (prepared in 600 mL beakers)

- 1-stage mixing: 500 rpm, 20 min
- 2-stage mixing: 1200 rpm, 0.5 min followed by 300 rpm, 20 min

Two-stage mixing results in polymer solution of much better quality

* High energy first: prevent fisheye formation

* Low energy followed: minimize polymer damage



UGSI Solutions

(2) **Residence Time** of Low Energy Mixing Zone

SNF POLYDYNE

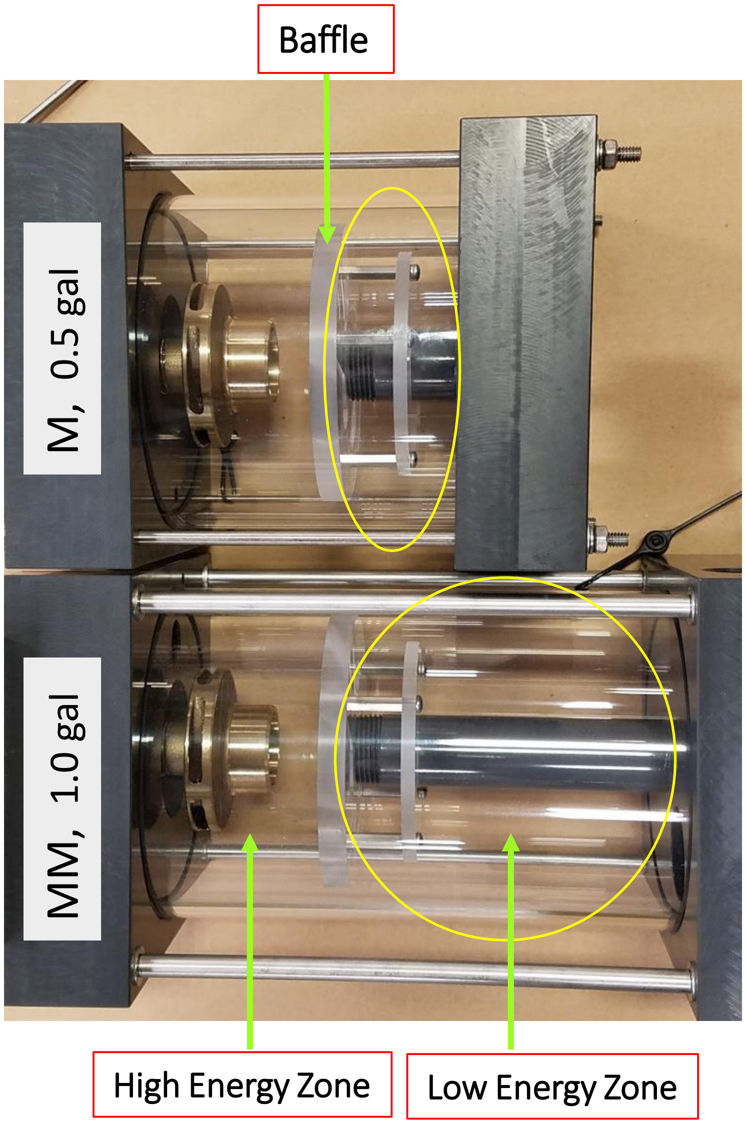
CLARIFLOC® WE-1181 POLYMER

SOLENIS™

PYM-PDS-NA-Praestol Cationic Polymers

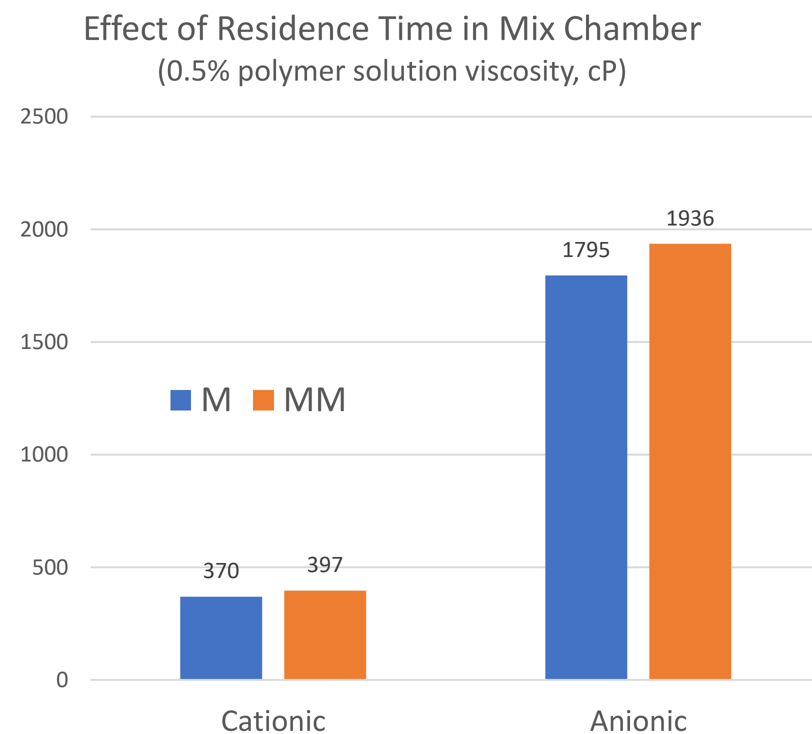
There are a number of commercially available automatic feed systems that provide in-line mechanical mixing. The best units of this type feature initial high energy mixing (>1000 rpm) for a short time (<15 sec) to achieve good dispersion of the product into water. This is followed by lower energy mixing (<400 rpm) for a longer period of time (10-20 min) and aging for an additional 10-20 minutes to achieve complete polymer dissolution. Best practice is to use these in-line dilution systems followed by a mixing/aging tank fitted with high/low level probes to refill the tank. The optimum concentration in the mixing/aging tank is 0.5 percent, and in no case should the initial concentration of polymer be less than 0.25 percent for best res

Effect of Residence Time in Mix Chamber



Volume of low-energy zone: V_L

$$V_{L,MM} = 3 * V_{L,M}$$



UGSI Solutions

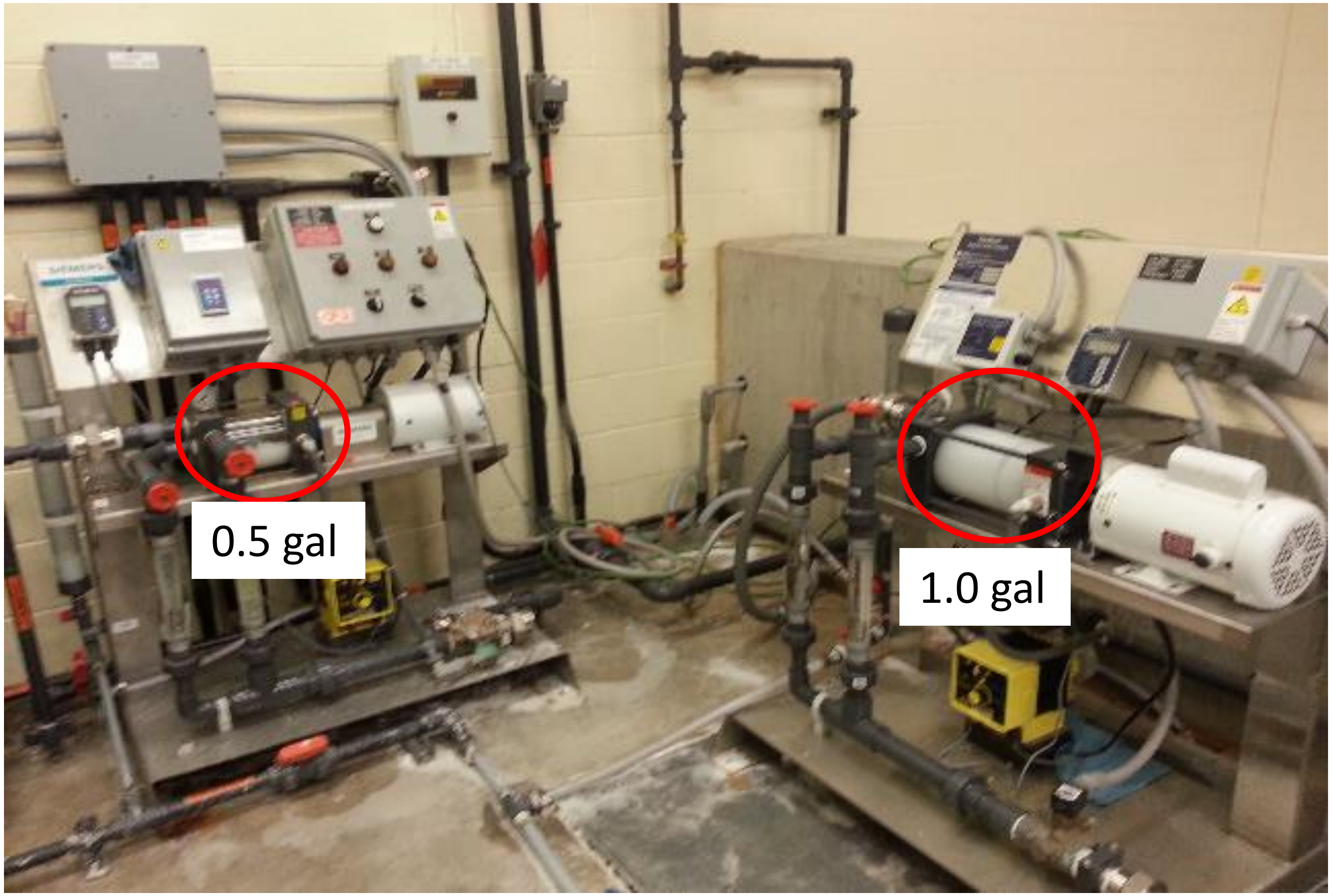
Case Study: Emulsion Polymer System
Neshaminy Water Treatment Plant, PA

- Located Northeast Philadelphia
- Operating capacity: 16 MGD
- Population served: 40,000
- Anionic HMW emulsion polymer used for dewatering alum-carbon sludge with two 2-M belt filter presses (K-S)

UGSI Solutions

Performance Comparison of Two Mix Chambers

Praestol A3040L- Anionic, Linear Emulsion Polymer



Existing Polymer System
Siemens M1200-D10AA (2011)

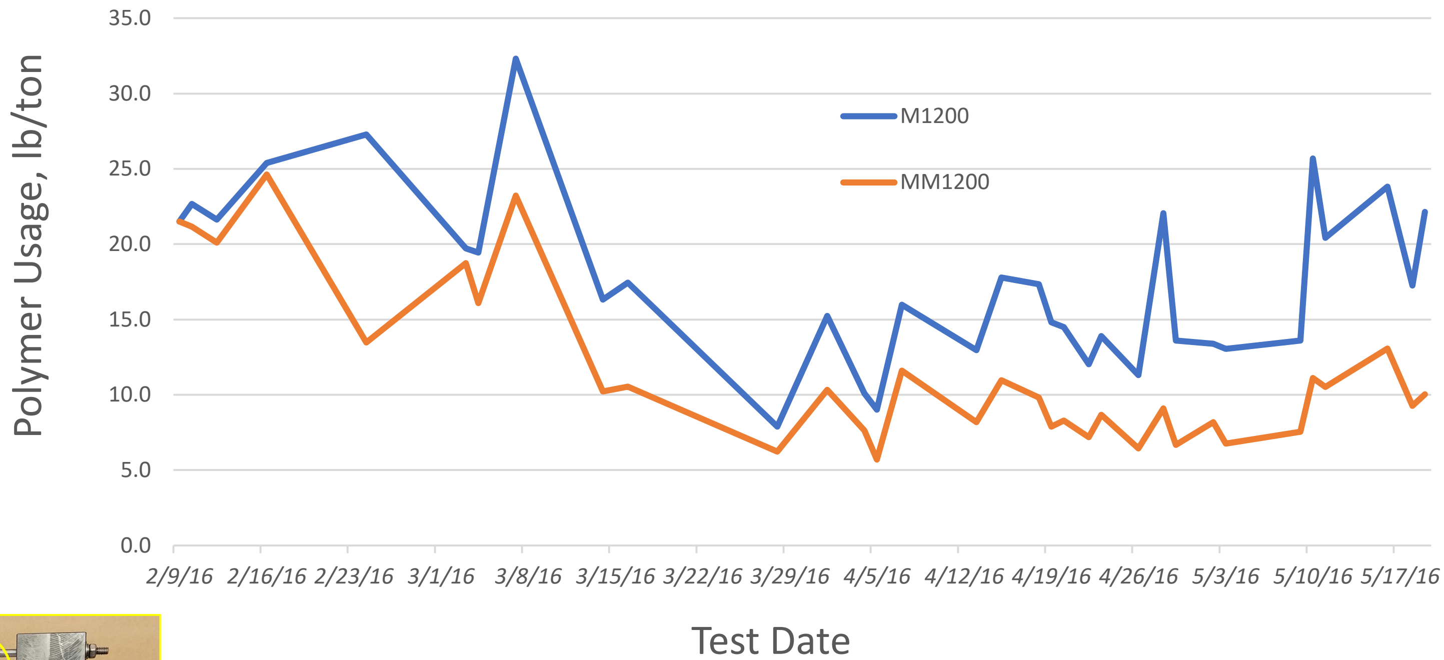
New Polymer System
UGSI MM1200-D10AA (2016)

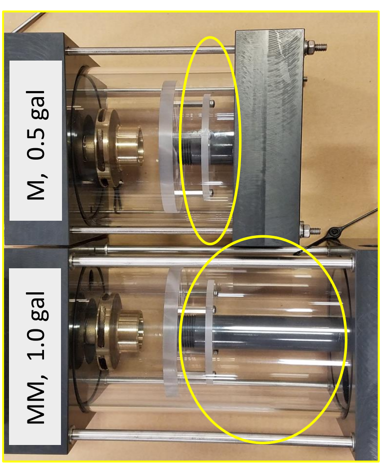
UGSI Solutions

Impact of Residence Time of Low-Energy Mix Zone

Neshaminy Water Treatment Plant, PA

Polymer Usage of Two PolyBlend Systems





- Side-by-Side Trial from Feb to May 2016
- ***Polymer savings > 30%***
- ***Sludge throughput increased by 10%***
- *Cake solids improved marginally from 22% to 23%*

UGSI Solutions

Third Party Study: Emulsion Polymer System

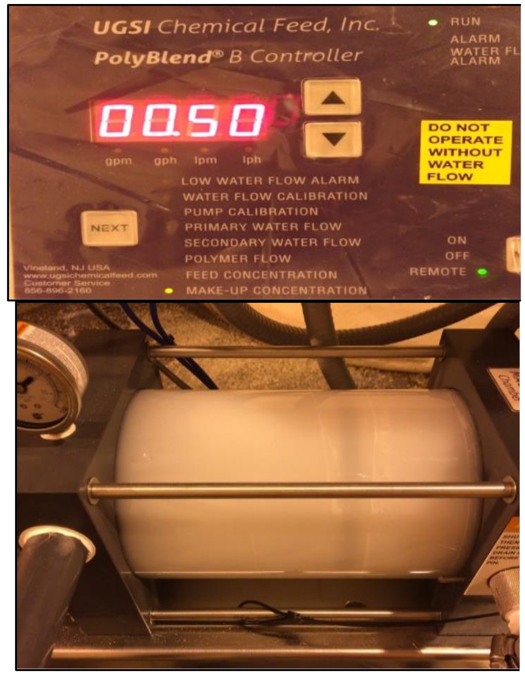
F. Wayne Hill WRC, Gwinnett County, GA

- Design capacity: 60 MGD
- Annual cost of polymer is significant ($1.2 million)
  - Thickening ~ $400,000 (RDT)
  - Dewatering ~ $800,000 (Centrifuge)
- SNF/Polydyne Clarifloc SE-873: Cationic, branched

Courtesy - Jacobs Engineering and Gwinnett County

Three Polymer Systems for Pilot Trials

Optimum feed concentration: 0.5% - 0.7%



FloQuip EA70P

One-stage mixing
3,450 rpm

UGSI MM2400-P30AB

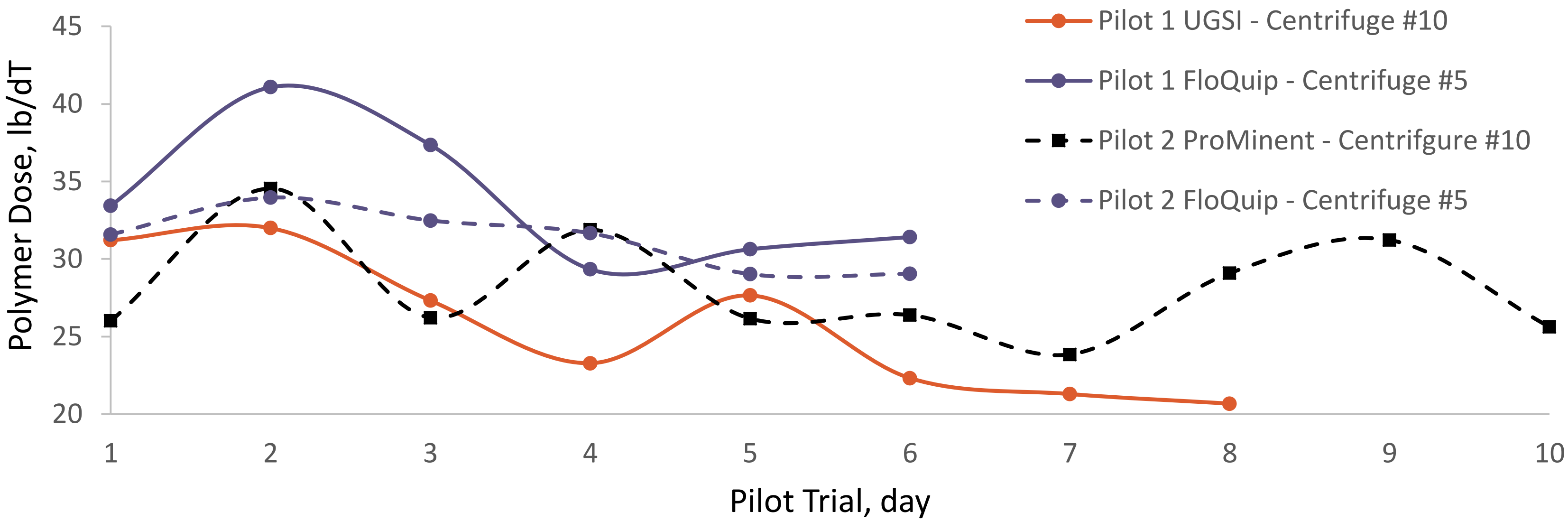
Two-stage mixing
3,450 rpm

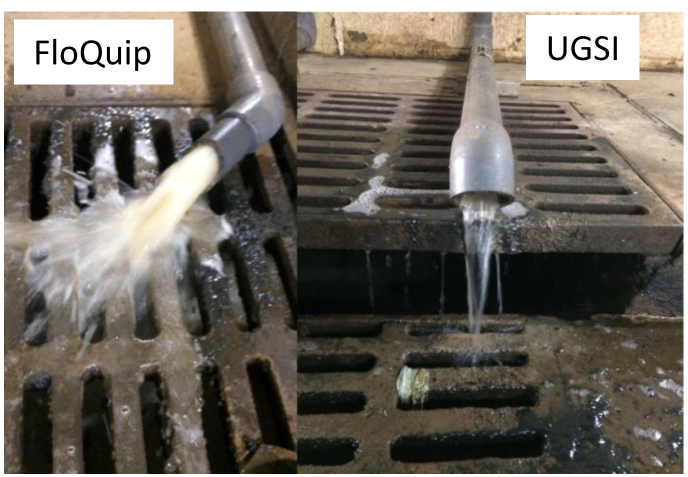
ProMix L6000-30P

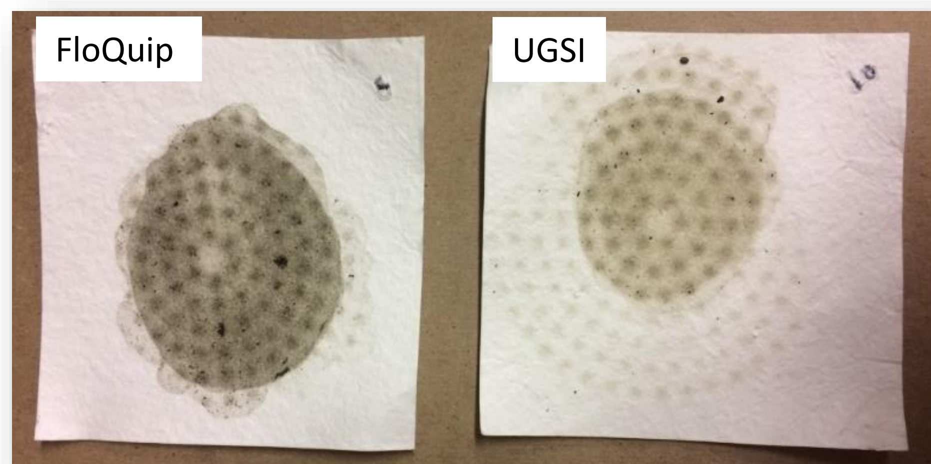
Three-stage mixing
1,725 rpm

Courtesy - Jacobs Engineering and Gwinnett County

Polymer Dose during Each Pilot Test







Courtesy - Jacobs Engineering and Gwinnett County

Trial results demonstrate that UGSI two-stage mixing provides significant polymer savings vs. FloQuip

Test	Polymer Blending Unit & Centrifuge	Average Polymer Dose (lb/dT)	Centrifuge Sludge Feed Flow Range (gpm)	Average Dry Cake Solids, TS (%)	Average Centrate TSS (mg/L)	Optimum Conc. Polymer Solution (%)
Pilot 1	PolyBlend 2-Stage	25.7	100 - 180	20.4	184.4	0.45 - 0.50
	FloQuip 1-Stage	33.9	100 - 200	21.5	193.5	0.70
Pilot 2	ProMix 3-Stage	28.0	100 - 180	20.1	190.6	0.50
	FloQuip 1-Stage	31.3	100 - 200	21.7	183.0	0.70

- PolyBlend® MM: **25% less** polymer dosage, lower centrate TSS than FloQuip.
- ProMix® L: **10% less** polymer, higher centrate TSS than FloQuip.
- PolyBlend® MM is expected to provide an **annual savings of $200,000** for dewatering only.

Courtesy - Jacobs Engineering and Gwinnett County

Summary

- Good quality dilution water yields to more efficient polymer solution
- Polymer activation
  - Two-stage mixing: very high-energy mixing at the moment of initial wetting (MOIW) is critical to prevent fisheye formation, followed by low-energy mixing to minimize damaging polymer chain
  - Sufficient residence time of low-energy mixing stage is required to achieve fully dissolved homogeneous solution
  - Selection of mechanical or non-mechanical mixing system
- Case Studies
  - Neshaminy WTP – Sufficient residence time
  - FWHWRC (WWTP) – Two-stage mixing

Thank You

Any Questions?

ykim@UGSIcorp.com

UGSI Solutions