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Polymer 101: Fundamentals of Flocculation

Thursday, June 25, 2020

1:00 – 2:30 PM ET

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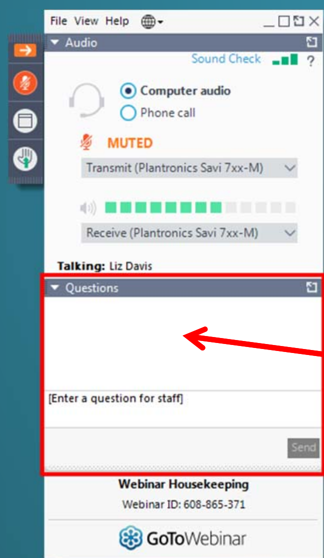
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
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- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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Today's Moderator

Ed Fritz, P.E. BCEE
HUBER Technology, Inc.
Denver, NC

HUBER TECHNOLOGY
WASTE WATER Solutions

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Polymer 101:
Fundamentals of Flocculation

- Chemistry, Handling/Storage, Dilution Water, and Optimized Mixing
  Yong Kim, Ph.D.
- Practical Ways to Improve Performance – Laboratory Testing
  George Tichenor, Ph.D.
- State-of-the-Practice in Biosolids/Polymer Blending for Biosolids Dewatering
  David W. Oerke, P.E. BCEE

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Polymer 101: Chemistry, Handling/Storage, Dilution Water, Optimized Mixing

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

UGSI Solutions

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Presentation Overview

1. Coagulation and Flocculation
2. Basic Polymer Chemistry
   - Ionicity, Molecular Weight, Active Content, Particle Size, Viscosity
3. Polymer Type
   - Dry, Emulsion, Mannich Polymers
4. Handling and Storage
5. Polymer Make-Down (Solution Preparation)
   - Effect of Dilution Water
   - Two-Stage Mixing
   - Two-Step Dilution
   - Adequate Residence Time
6. Polymer Make-Down Equipment
   - Mechanical vs Non-Mechanical Mixing
7. Aging of Polymer Solution

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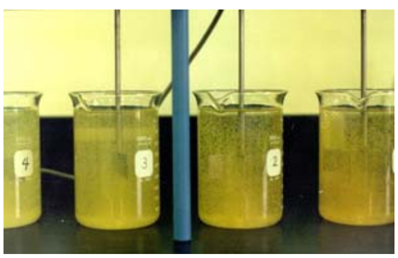
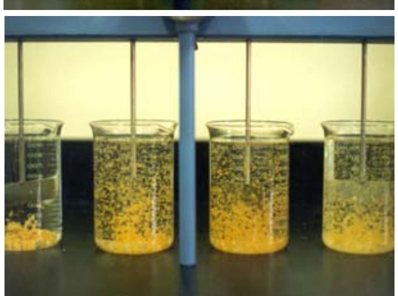
Coagulation and Flocculation



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)

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Polymer Structure

- Polymeric Flocculant, Linear Polymer, Polyelectrolyte
- Chained Structure by Repetition of Monomers

$$\ldots - CH_2 - \underset{\underset{NH_2}{|}}{\underset{CO}{CH}} - [CH_2 - \underset{\underset{NH_2}{|}}{\underset{CO}{CH}}]_n - CH_2 - \underset{\underset{NH_2}{|}}{\underset{CO}{CH}} - \ldots$$

Most polymers in water industries are acrylamide-based.

If molecular weight of polymer is 10 million,
the number of monomers in one polymer molecule, *"degree of polymerization"*

n = 10,000,000 / 71
= 140,850

(mol. wt. of monomer, acrylamide = 71)

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Physical Types 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: 0.1 - 2 mm
- Cost: high

Emulsion Polymer
- Cationic, anionic, non-ionic
- Molecular weight: up to 10 M (cationic), up to 20 M (anionic, non-ionic)
- 30 - 60% active
- Polymer gel size: 0.1 - 2 µm
- Cost: high

Solution Polymer (Mannich)
- Cationic only
- Molecular weight: up to 10 M
- 4 - 6% active
- Cost: low
- Limited usage

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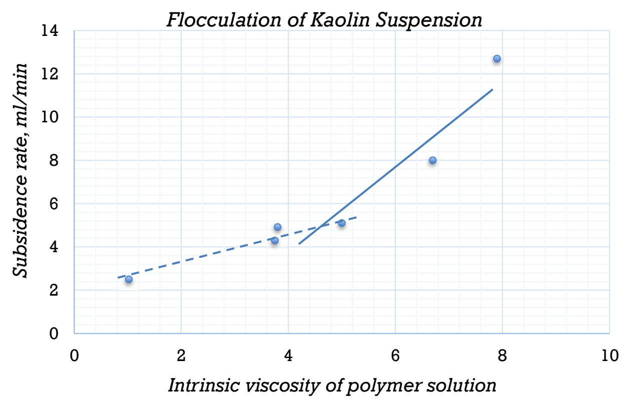
Viscosity – Indicator of Polymer Solution Efficiency

Quantity of friction as measured by the force resisting a flow in which parallel layers have at unit speed relative to one another



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

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Handling & Storage

Shelf Life:
- Emulsion: 6 months, un-opened drum/tote
- Dry: up to 3 years, un-opened bag
- Polymer solution: depends of 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, etc.)
- Always consult SDS

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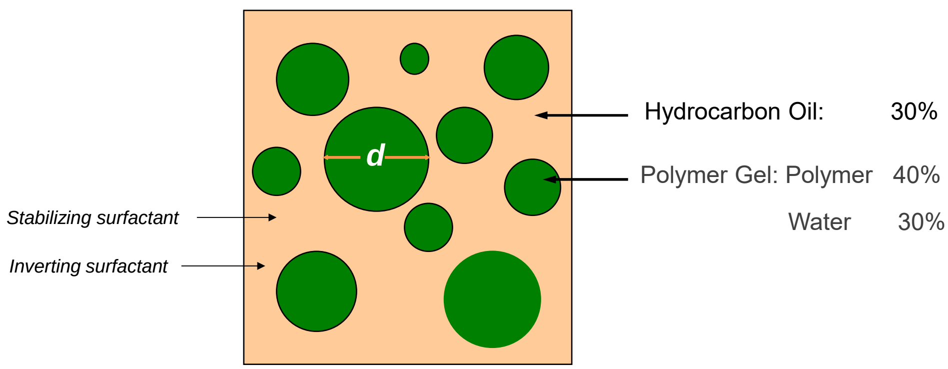
Configuration of Emulsion Polymer



d = 0.1 - 2 μm

Specific gravity difference between hydrocarbon oil and polymer gels

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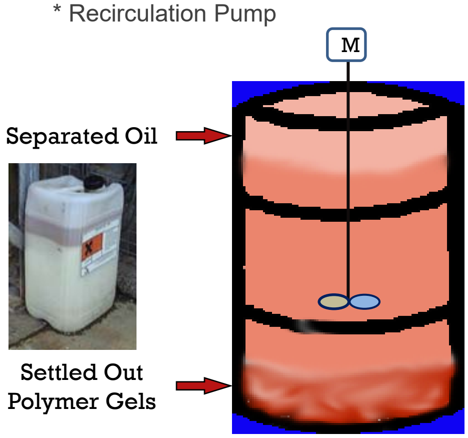
Storage of Emulsion Polymer

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



- Moisture Intrusion
  - * Drum (Tank) Dryer

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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

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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 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

David Oerke, et al, Proceedings of Residuals and Biosolids Conference (2014)

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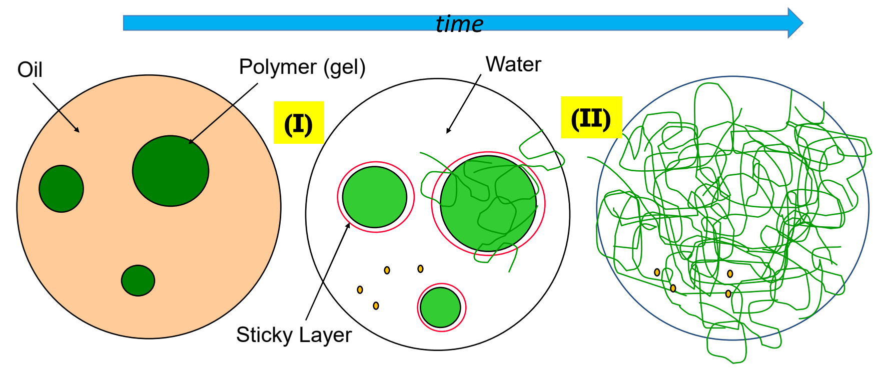
Polymer Activation (Mixing, Dissolution)

(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)*

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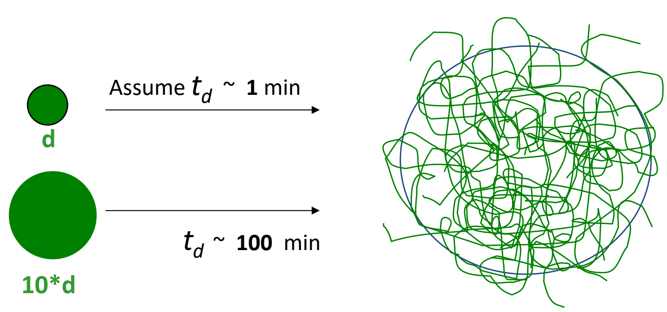
Why High-Energy Mixing at Initial Wetting is Critical?

Polymer dissolution time, t_d ~ (diameter)^2 *Tanaka (1979)**



Initial high-energy mixing → No fisheye formation → Significantly shorter mixing time

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

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Two-Stage Mixing in a mix chamber
higher energy mixing → low energy mixing

SNF POLYDYNE

CLARIFLOC® WE-1181 POLYMER

TYPICAL PROPERTIES

Physical Form	Clear to Milky White Liquid
Cationicity	60%
Active Polyacrylamide Min.	45.0 %
Freezing Point	7 F. (-14 C.)
Flash Point	>200 F. (>93 C.)
Density	TBD

PREPARATION AND FEEDING

CLARIFLOC WE-1181 is a single component emulsion polymer that must be pre-diluted in water before use. In most cases, this product should not be applied neat. One method for dilution is adding the neat polymer into the vortex of a mixed tank at a concentration between 0.25-1.0% polymer (0.5% is optimum) by weight. The polymer can also be injected through a number of commercially available systems that provide in-line mechanical mixing. The best feed systems use initial high energy mixing (>1000 rpm) for a short time (<30 sec) to achieve good dispersion followed by low energy mixing (<400 rpm) for a longer time (10-30 min). Polymer solutions should be aged for 15-60 minutes for best results. Solution shelf life is 8-16 hours.

SOLENIS™

YM-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 results.

"Discrete" Two-Stage Mixing - discrete means "separation of high and low energy mixing zones"

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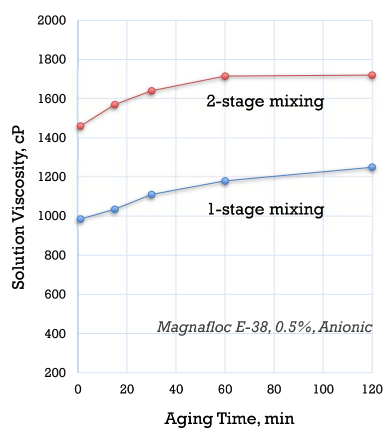
Two-stage vs One-stage Polymer Mixing

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



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Two-Step Dilution with post-dilution

primary mixing at high %, then post-dilution to feed

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SOLENIS

PYM-PDS-NA-Praestol Cationic Polymers

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High Concentration* at Initial Wetting,
Optimum 0.5% wt. = 1.0 ~ 1.5% vol.
Need to post-dilute to < 0.5% vol.

* *AWWA Standard for Polyacrylamide (ANSI-AWWA B453-06), 11, 2006*

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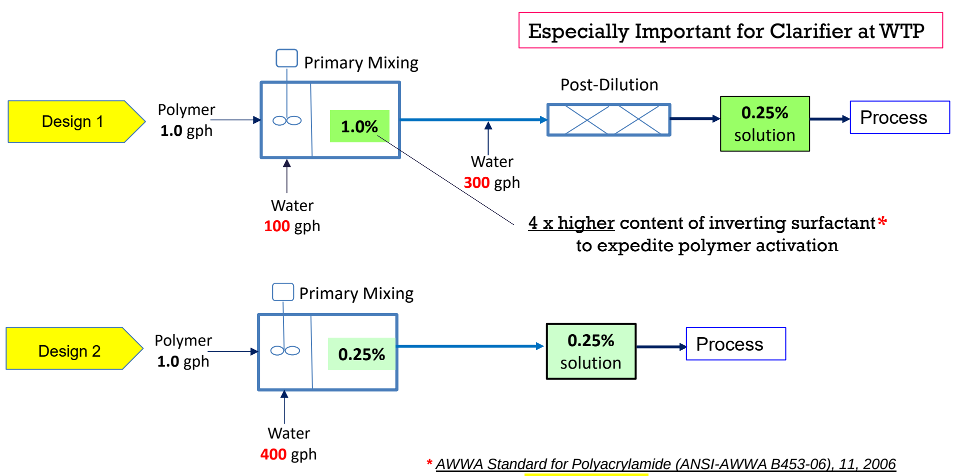
Two-Step Dilution facilitates Polymer Activation

Primary mixing at high conc. → Post-dilution to feed conc.



* *AWWA Standard for Polyacrylamide (ANSI-AWWA B453-06), 11, 2006*

To enable "inverting surfactant" to work properly, make polymer solution at high concentration

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Residence Time of low-energy mixing zone

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Low energy mixing stage requires longer residence time than initial high energy mixing stage

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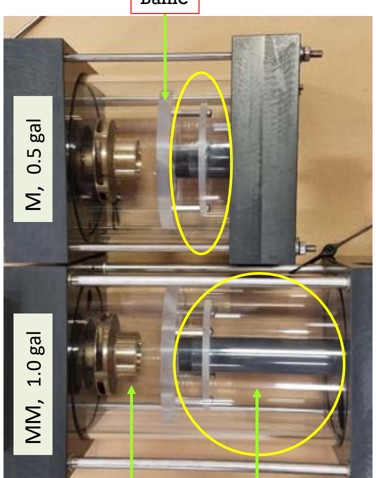
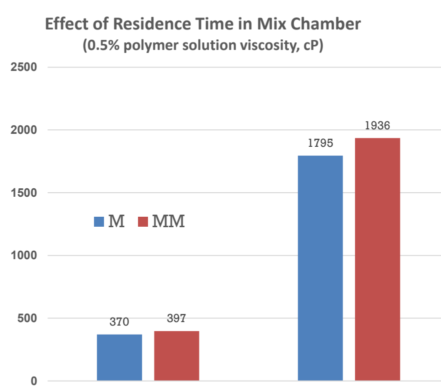
Residence Time Effect of mix chamber



Volume of low-energy zone: V_L

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



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Mechanical vs Hydraulic Mixing

Key is how to provide high mixing energy at initial wetting

Mechanical Mixing

Mean Shear Rate

$G = (P / \mu V)^{1/2}$

G: mean shear rate
P: power delivered to fluid
μ: viscosity
V: mixing volume

- Mixing energy easily determined
- Very high mixing energy at initial wetting
  Not depends on water pressure
- No mechanical mixing at second stage
- Efficient for wide variety of polymer types
  Low to very high molecular weight

Hydraulic Mixing

Contact Force

$Sum(F) = Sum(\beta * m * V_{out}) - Sum(\beta * m * V_{in})$

F: force, m: mass
β: momentum flux correction factor
V_{in}: velocity in the x direction, zero in y
V_{out}: V*cos(θ) in the x-direction
V*sin(θ) in the y-direction
θ: bending angle

- Mixing energy not easily determined
- High mixing energy at initial wetting
  Depends on water pressure, booster pump?
- No mechanical mixing at second stage
- Efficient for variety of polymer types
  Low to medium high molecular weight

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Aging of Polymer Solution

Polymer Property, Initial Wetting, Water Quality

Aging may help:

* Very high molecular weight, low charge density polymers, or
* Initial wetting done by poor energy mixing

Aging may not help:

* Medium molecular weight, high charge density polymers, or
* Initial wetting done by very-high energy mixing

Aging may hurt:

* Reclaimed or bad-quality water for polymer mixing, or
* Low concentration of polymer solution, or
* Extended aging time

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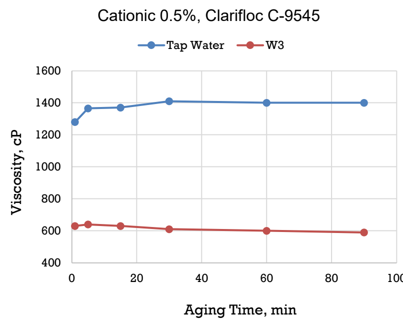
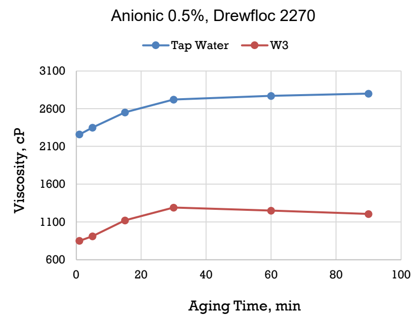
Aging – Use of Tap Water vs Reclaimed Water

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 > 10 - 30 min

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Thank You

Any Questions?

YKim@UGSIcorp.com

UGSI Solutions

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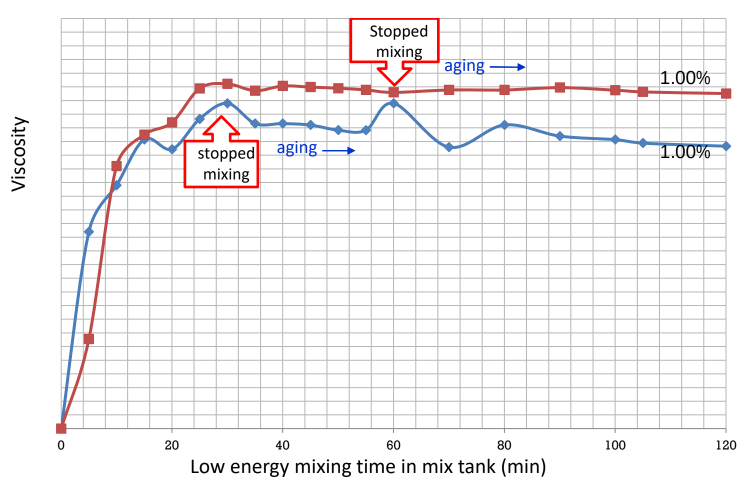
Aging – Importance of Initial Wetting

Viscosity of dry polymer solution after very-high energy mixing at initial wetting (3,450 rpm) followed by low energy mixing (60 rpm)



Rao, M, Influents (WEA Ontario, Canada), Vol. 8, 42 (2013)

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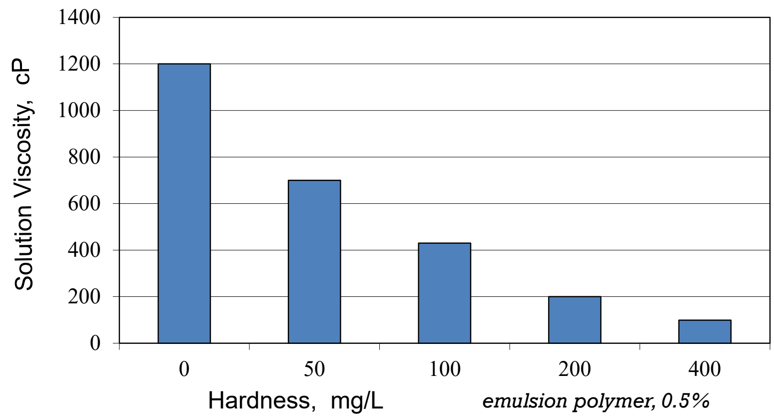
Effect of Dilution Water Hardness

Soft water helps polymer chains to be fully extended



Kim, Y.H., Coagulants and Flocculants: Theory and Practice, 43, Tall Oak Pub. Co. (1995)

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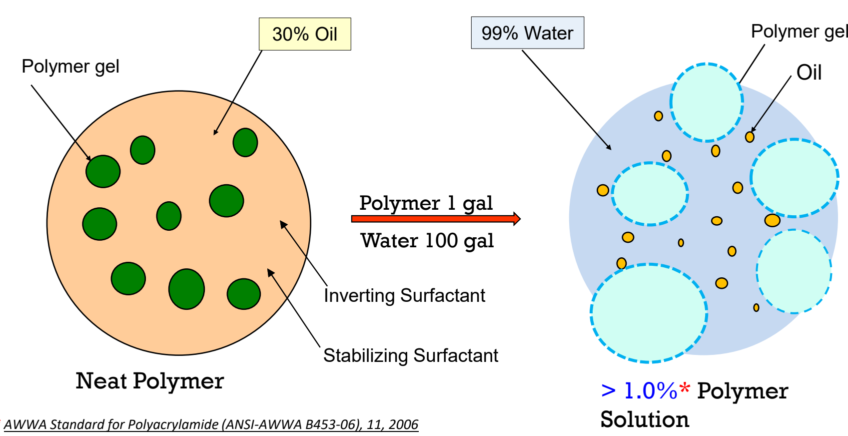
Inversion of Emulsion: water-in-oil → oil-in-water

Inverting (Breaker) Surfactant

Especially Important for Clarifier at WTP

Strips "oil" off the polymer surface
- helps polymer get exposed to water quickly
- breaks and disperse oil in micron size



* *AWWA Standard for Polyacrylamide (ANSI-AWWA B453-06), 11, 2006*
To enable inverting surfactant to work properly, make polymer solution at high concentration

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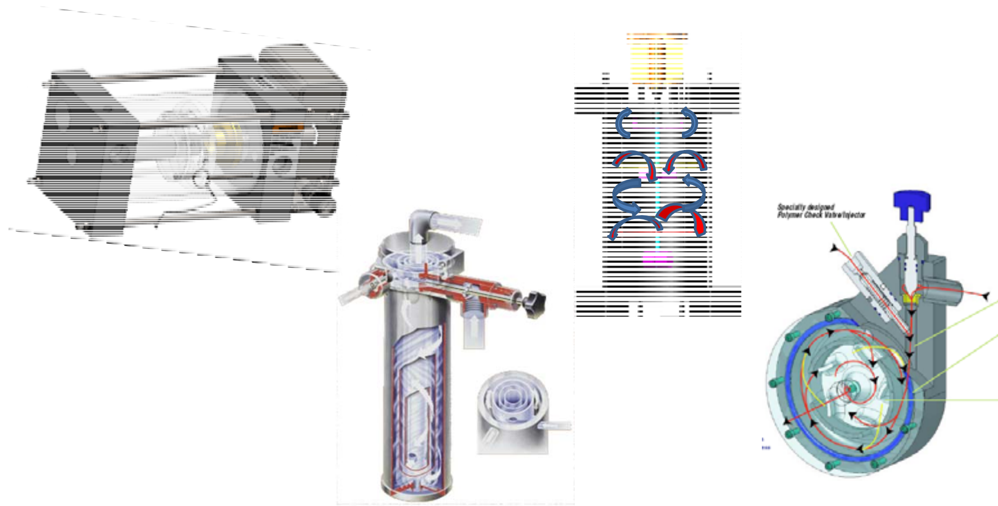
Mechanical vs Hydraulic (non-mechanical) Mixing



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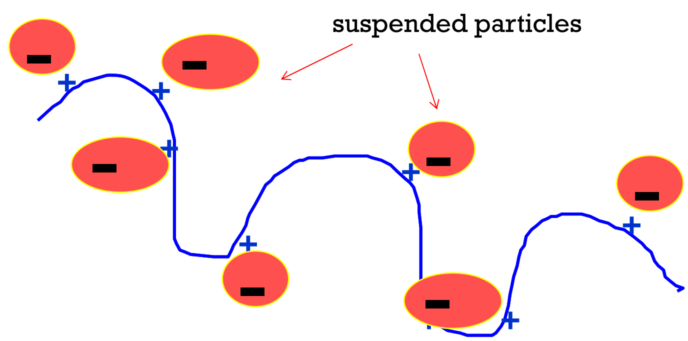
Flocculation - Bridging by Polymer Molecules



Extended cationic polymer molecule attracts negatively-charged suspended particles

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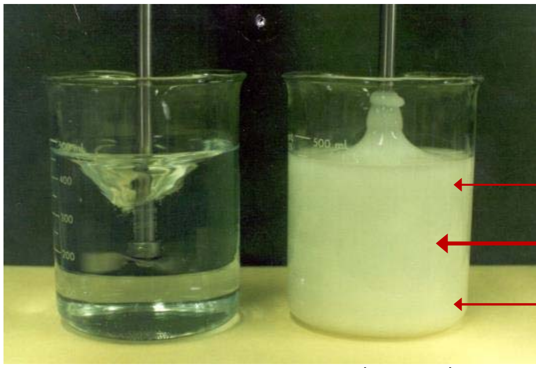
Weissenberg Effect - mixer shaft climbing

* Polymer solution exceeding “critical concentration” climbs up mixing shaft
* Extremely non-uniform mixing
* Critical factor for “conventional” polymer mix tank → max 0.25% limit for HMW polymer



extremely low mixing

very high mixing

extremely low mixing

Water
(Newtonian)

Polymer Solution
(Non-Newtonian, Pseudoplastic)

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SNF

George Tichenor, Ph.D.

Sr. Applications Scientist

SNF Inc.

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Dewatering Optimization: Practical Ways to Improve Performance - Laboratory Testing

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Topics

Laboratory polymer makedown

Polymer dosage calculation

Solids Consolidation Tests

- **Pour Test**
- **Gravity Drainage Test (AKA Free Drainage or Buchner Funnel Test)**
- **Chopper Test**

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Laboratory Polymer Makedown

Plant polymer makedown water

Emulsion flocculants

- **0.20 – 1.00% product**
- **Inject *all-at-once* into rapidly-stirred water vortex**
- **Continue to mix 15 min.**

Powder flocculants

- **0.10 – 0.50% product**
- **Pour *slowly* into rapidly-stirred water vortex**
- **Continue to mix until the solution is homogeneous**

Allow 15 min. for polymer to "relax"

Shelf-life

- **Anionic makedowns: stable for 1 week**
- **Cationic makedowns: make down daily**

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Polymer makedown video:
Powder dissolution
Emulsion inversion
(just showing polymer addition)

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Polymer Dose

Polymer dose is measured in lbs. of polymer per dry ton of solids

$$\text{Polymer Dose (lbs/ton)} = \frac{2000 \times P \times p}{F \times f}$$

Where P = Polymer Rate (gpm)*
p = Polymer Concentration (% polymer product)
F = Sludge Feed Rate (gpm)*
f = Sludge Feed Concentration (% sol.)

* or volume (in mL) for lab testing

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Polymer Dose

Calculation Example

$$\text{Polymer Dose (lbs/ton)} = \frac{2000 \times P \times p}{F \times f}$$

P = 15 gpm
p = 0.50 % polymer product
F = 300 gpm
f = 2.50% sludge solids

$$\text{Polymer Dose} = \frac{2000 \times 15 \times 0.50}{300 \times 2.5} = 20 \text{ lbs/ton}$$

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Pour Test

General test for flocculation

Good starting point for Gravity Drainage or Chopper Test dosage curves

Procedure: Add polymer to untreated sludge and mix

Equipment and supplies:

- Untreated sludge
- 400 or 500 mL beakers
- Made-down polymer solutions
- Syringes

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Pour Test video:
Non-BPR sludge
200 mL + 11.4 mL 0.50% poly,
16 pours

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Pour Test

UNDERDOSED

OPTIMUM

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Gravity Drainage Test

Simulation of filtration applications

Variables

- **Polymer dosage, concentration and aging**
- **Polymer – sludge mixing**
- **Sludge thruput**

Procedure: Add polymer to untreated sludge, mix, filter and measure filtration rate

Equipment and supplies

(Pour Test equipment plus…)
Buchner Funnel/appropriate filter medium
250 mL graduated cylinder
Stopwatch

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Gravity Drainage Test video:
Dig. non-BPR sludge

1. 200 mL + 11.4 mL 0.50% poly, 16 pours, 34.3#/T
2. 200 mL + 10.0 mL 0.50% poly, 16 pours, 30.0#/T

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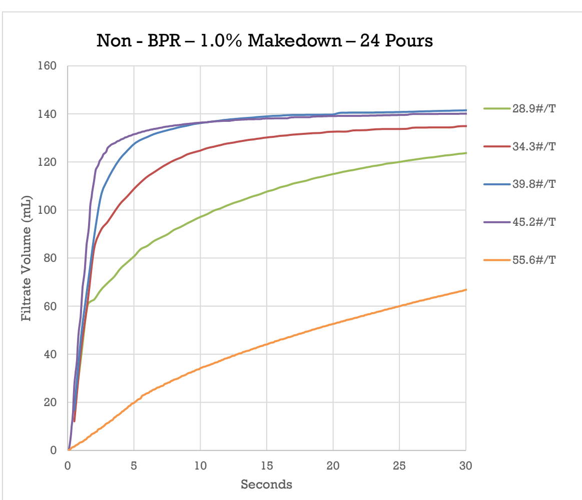
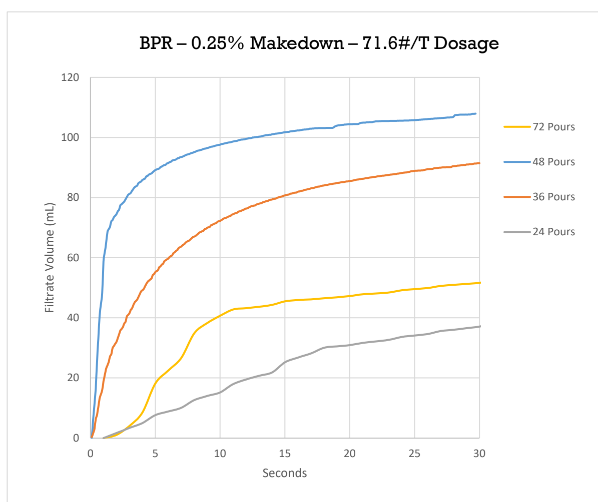
Gravity Drainage Test



Dosage curve



Mixing curve

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Gravity Drainage Test

Sludge type:

Anaerobic digested sludge

	Feed (% Sol.)	Dosage (#/T)	Cake (% Sol.)
Non-BPR	1.66	34.3	8.58
BPR	2.70	71.6	5.76

Chopper Test

Simulation of high-shear applications

Variables
- **Polymer dosage, concentration and aging**
- **Polymer – sludge mixing**
- **Sludge thruput**

Procedure: Mix polymer and untreated sludge at high shear

Equipment and supplies
- **(Pour Test equipment plus…)**
- **Black & Decker 1-Cup Chopper**
- **Electronic timer or (stopwatch)**
- **100 mL graduated cylinder**

Chopper Test video:
Dig. BPR sludge

1. 100 mL + 9.5 mL 1.00% poly, 10 sec., 70.4#/T
2. 100 mL + 10.0 mL 1.00% poly, 10 sec., 74.1#/T
3. 100 mL + 9.0 mL 1.00% poly, 10 sec., 66.7#/T

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Chopper Test

Sludge type:

Anaerobic digested sludge

	Feed (% Sol)	Dosage (#/T)	Cake (% Sol.)
Non-BPR	**1.66**	**47.0**	**7.53**
BPR	**2.70**	**74.1**	**5.06**

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Summary

Optimize performance variables
- Polymer dosage
- Polymer aging
- Polymer concentration
- Polymer/sludge mixing
- Sludge throughput

By appropriate bench-scale testing
- Pour Test
- Gravity Drainage Test
- Chopper Test

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SNF

Thank You!

Questions?

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State-of-the-Practice in Biosolids/Polymer Blending for Biosolids Dewatering

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Jacobs Engineering
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Outline of Presentation

1. Background
2. Historical Polymer Use and Existing Equipment
3. Polymer Investigation
4. Polymer System Recommendations
   - A. Centrifuge system
   - B. RDT system
   - C. Chemical system
5. Costs and Payback Period
6. Conclusions and Recommendations

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FWHWRC Solids Processing Facilities

- PSL and WAS mixed and stored in phosphorus release tanks for nutrient recovery
- Co-thickening of PSL and WAS in six rotary drum thickeners (RDTs)
- Anaerobic co-digestion of thickened combined solids with FOG and HSW in egg-shaped digesters
- Two stabilized liquid biosolids storage tanks
- Centrifuge dewatering of digested biosolids and chemical solids from tertiary treatment process with six (five in use) centrifuges
- Landfill disposal of biosolids
- Filtrate and centrate used to feed nutrient recovery system utilizing struvite precipitation

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Six Major Project Goals and Success Factors

1. Improve safety with grating and non-slip surfaces
2. Provide improved polymer dose control/instrumentation for aging polymer system equipment
3. Improve equipment O&M access, redundancy and operational flexibility
4. Maintain cake concentration and solids capture [(less than 200 parts per million (ppm) to nutrient recovery]
5. Add polymer system for Chemical Solids Thickeners
6. **Reduce overall polymer consumption AND save some money**

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Summary of Monthly FWHWRC Centrifuge and RDT Polymer Dosage, Cost and Performance – February 2016 through August 2018

Process Equipment	Polymer Dosage (lb-act/dT)	Polymer Dosage ($/dT)	Bulk Polymer ($/mo.)	Cake Dryness (%)	Capture Rate (%)	Centrate TSS (mg/L)
Dewatering Centrifuge	31.8	$64.13	$66,852/mo. X 12 = $802,208/year	23.6	99.4	191.0
Rotary Drum Thickener (RDT)	8.3	$20.77	$33,509/mo. X 12 = $402,112/year	7.5	99.0	209.1
			Total $1,204,320/year			

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Existing Centrifuge Polymer System

- 3 bulk emulsion polymer storage tanks
- 4 SNF Floquip EA70P skids (1-stage)
- 34 gph neat polymer
- 70 gpm (@ 0.70% Solution)
- Each skid feeds into 1 set of mixing/aging tanks (4 tanks total)
- 5 undersized 32 gpm 2-inch hose pumps with frequent hose breaks and maintenance

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Issues with Existing Centrifuge SNF Floquip Polymer System

- Installed in 2003; not reliable
- Neat emulsion polymer separating in bulk tank; need mixing pumps
- Performance, polymer solution concentration and dilution water varies based on plant water flow and pressure
  - low pressure = low mixing energy
- Water booster pump is required
- No post-dilution used
- 1-stage mixing not enough time for effective activate emulsion polymer without significant aging
- Difficult to mix polymer solution with thick feed solids (2.8 to 3.3%)
- Polymer solution can only be pumped to 5 of 6 centrifuges (centrifuges No. 5, 7 and 9 share polymer piping)

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Existing RDT Polymer System

- 6 Fluid Dynamics Dynablend skids
  - 4 gpm neat polymer capacity
  - 600 gph polymer solution capacity (flow-paced)
- Relatively low RDT polymer dose
  - But, polymer solution concentration and dilution water is inconsistent and difficult to control; relies on variable water pressure
- High operational attention and maintenance requirements
  - High variability in thickened solids concentrations
  - Target is 7.0 – 7.5%, varies between 2 and 12%
  - Frequent maintenance issues with TWAS pumps
- Inadequate O&M access

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Chemical Thickeners and Recommendations

Process Control:
- Previous experience with temporary polymer system
  - Worked well, but poor controls led to system overdose
- Chemical solids feed pumps feed centrifuge directly

Polymer Blending Units:
- Construct permanent polymer feed system

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GCDWR Wants a State-of-the-Practice Polymer Preparation System for Complete Polymer Dissolution (5 components)

1. 2-stage mixing
   a. 1st stage includes high energy (G value of 4,000 sec^{-1}; approx. 1,000 rpm) for 30 seconds to achieve good dispersion
   b. 2nd stage includes lower energy (G value of 1,100 sec^{-1}; approx. 400 rpm) for 10-30 seconds to uncoil the polymer chains
2. Aging for 15-30 minutes (insurance)
3. Post-dilution of polymer solution to 0.10 to 0.20% (average of 0.15%)
   a. 3 to 4X better mixing with biosolids with thinner solution
   b. Preferred by process engineers at Alfa-Laval (existing centrifuges) and Parkson (existing RDTs)
4. Automation systems
   a. Pace polymer by the amount of mass [flow X concentration (using TS analyzer information)
   b. Revise the dose based on centrate/filtrate TSS
5. PLC tie to plant-wide SCADA system
   a. Monitoring, Trending and Control

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Polymer Suppliers Recommend 2-Stage Mixing: Higher Energy Mixing Followed by Low Energy Mixing

SNF POLYDYNE

CLARIFLOC® WE-1181 POLYMER

TYPICAL PROPERTIES

Physical Form	Clear to Milky White Liquid
Cationicity	60%
Active Polyacrylamide Min.	45.0 %
Freezing Point	7 F. (-14 C.)
Flash Point	>200 F
Density	TBD

0.5% by weight is more than 1.0% by volume for primary mixing.

PREPARATION AND FEEDING

CLARIFLOC WE-1181 is a single component emulsion polymer that must be pre-diluted in water before use. In most cases, this product should not be applied neat. One method for dilution is adding the neat polymer into the vortex of a mixed tank at a concentration between 0.25-1.0% polymer (0.5% is optimum) by weight. The polymer can also be injected through a number of commercially available systems that provide in-line mechanical mixing. The best feed systems use initial high energy mixing (>1000 rpm) for a short time (<30 sec) to achieve good dispersion followed by low energy mixing (<400 rpm) for a longer time (10-30 min). Polymer solutions should be aged for 15-60 minutes for best results. Solution shelf life is 8-16 hours.

SOLENIS™

PYM-PDS-NA-Praestol Cationic Polymers

"discrete" two-stage mixing

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.

"Discrete" Two-Stage Mixing (discrete means "separation of high and low energy mixing zones")

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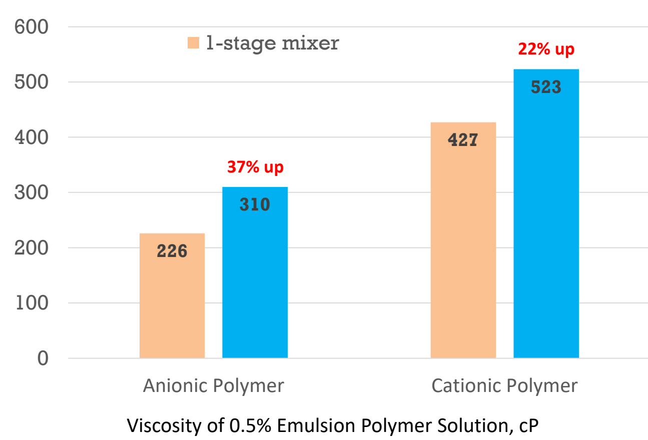
Two-Stage Mixing → Significant Performance Increase in Polymer Activation in Full-Scale Testing at Several WWTPs



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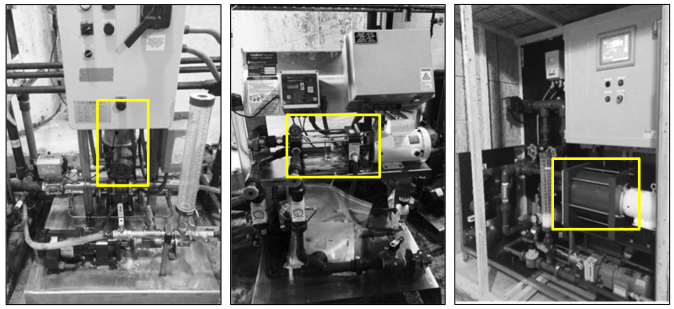
Existing and Pilot Polymer Blending Units



Manufacturer	SNF FloQuip	UGSI Chemical Feed Solutions	ProMinent Fluid Controls
Skid	Existing Centrifuge Skid	Pilot 1 Skid	Pilot 2 Skid
Model	EA- Series (EA70-P)	PolyBlend M-Series	ProMix L-Series Demo Skid
Capacity			
Polymer Feed Rate	0.03-0.57 gpm	0.5 gpm	*unknown*
Dilution W3 Flow Rate	30 – 70 gpm	20 gpm	50 gpm
Post Dilution W3 Flow Rate	N/A	20 gpm	50 gpm
Polymer Sol. Conc. Range	0.1 – 1.0%, Speed Dial	0.1 – 2.5%, 0.01% increments	0.1 – 1.0%, 0.01% increments
Mixing Chamber	Goulds centrifugal pump used in **one-stage** mixing chamber	UGSI patented Magnum **two-stage** multi-zone mixing, with clear mixing chamber	Large **three-stage** multi-zone mixing

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Conclusions: Two-Stage Pilot Equipment Versus Existing One-Stage Polymer Blending Equipment (cake solids & capture were similar, polymer was 10-25% lower for two-stage blending units) – need to balance cake, capture, & polymer

Test	Polymer Blending Unit & Centrifuge	Average Polymer Dose (lb-act/dT)	Centrifuge Sludge Feed Flow Range (gpm)	Average Dry Cake Solids, TS (%)	Average Centrate TSS (mg/L)	Average Percent Capture (%)
Pilot 1	UGSI PolyBlend Centrifuge #10	25.7	100 - 180	20.4	184.4	99.5 (± 0.1)
	SNF FloQuip Centrifuge #5	33.9	100 - 200	21.5	193.5	99.5 (± 0.1)
Pilot 2	ProMinent Centrifuge #10	28.0	100 - 180	20.1	190.6	99.5 (± 0.1)
	SNF FloQuip Centrifuge #5	31.3	100 - 200	21.7	183.0	99.5 (± 0.1)

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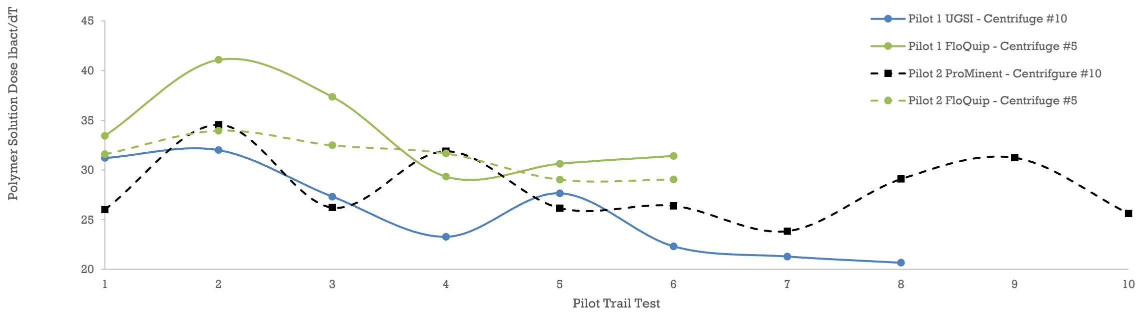
Conclusions: Two-Stage Pilot Equipment Versus Existing One-Stage Polymer Blending Equipment



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Comparison of Centrate Quality of Existing Single-Stage Versus Piloted Three-Stage Polymer Systems (Prominent)

Figure: Pilot 2 Centrate Observations for Centrifuge #5 (left) and Centrifuge #10 (right), December 20, 2017

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SNF FloMix Biosolids/Polymer Mixer Considered

- High energy mixing critical to efficiently mix polymer with thick solids
  - THP/digested biosolids – 4 to 6% feed solids
  - FWHWRC - 3 to 3.5% feed solids
- 8 polymer injection points
- In-line mounting with VFD allows the operator to adjust the mixer speed based on the feed solids concentration
- Low energy use (4 to 15 kW)
- Could be used as a second-stage supplemental mixer

Cost: 6-inch dia. $18,300 ea; 4-inch dia. $15,000 ea

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Success With Use of SNF FloMix

- THP digested biosolids installations with thick feed biosolids near London, UK
  - BFPs at Riverside STP (18 to 10 kg/tonne polymer, 2X throughput and 550 to 300 ppm filtrate)
  - BFPs at Cardiff STP (24 to 12 kg/tonne polymer, 2X throughput, 600 to 350 ppm filtrate)
  - 2 polymer addition points (one 60 seconds upstream of mixer, one upstream of floc tank/or at centrifuge). Jar testing suggested.
  - Used 0.3% polymer make-up concentration (0.1% too thin; 0.5% too thick)
  - The need for dilution of feed solids to 3-4% eliminated
- Being installed at HRSD Atlantic WRF for THP digested biosolids (4 to 8% solids)
- Being considered at FWHWRC for centrifuges

Potential Advantages: lower polymer dose, higher throughout and solids capture

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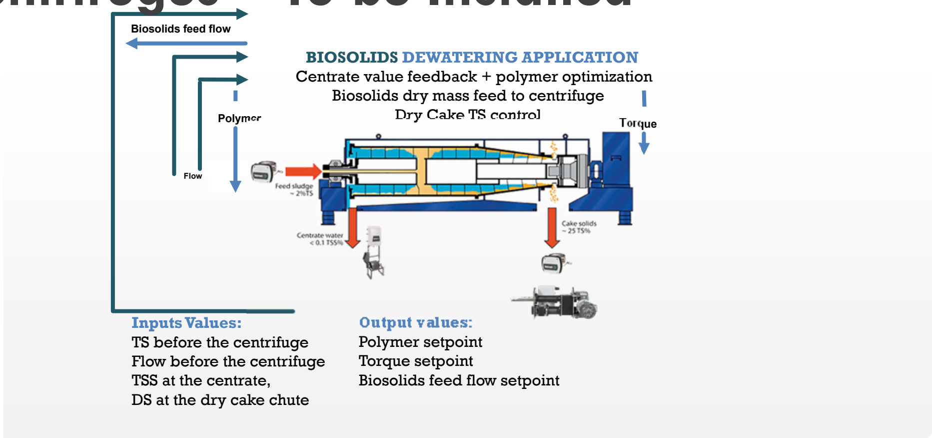
Valmet METSO TS and TSS Analyzers Pilot Tested on Centrifuges – To be Installed



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Centrifuge Polymer System Recommendations

Polymer Bulk Tanks:

- Add a 4th bulk storage tank
- Add bulk polymer mixing
- Safety additions to reduce overflow and containment

Polymer Blending Skids:

- Replace existing skids
  - Improve with 2-stage polymer activation
  - Improve O&M access to skids
  - Automate control of polymer solution concentration

Polymer Mixing/Aging Tanks:

- Operate as batch system
- Replace level instrumentation

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Centrifuge Polymer System Recommendations

Replace polymer feed pumps that are too small:
- Improve O&M access and safety; reduce maintenance
- Add 6th biosolids and polymer feed pump to match number of centrifuges
- Add individual polymer solution pipe to each centrifuge

Improve mixing of polymer solution with feed biosolids:
- Provide upstream polymer injection location
- Consider in-line mixer - successful at other WWTPs

Add TS instrumentation to centrifuge feed and centrate:

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RDT Polymer Facilities Recommendations

Polymer Blending Units:
- Replace blending units w/ 2-stage
  - Improve polymer activation
  - Automate control of polymer solution
  - Improve equipment HMI

Polymer Room Safety:
- Provide safety grating as walking surface

Add TS instrumentation to RDT feed solids/filtrate

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Estimated Construction Cost For All Polymer Improvements

Item	Cost
RDT Biological Solids Thickening Polymer Improvements*	$886,000
Centrifuge Dewatering Polymer Improvements*	$2,211,000
Chemical Thickening Polymer Improvements*	$345,000
Total Construction*	$3,442,000

** Includes electrical, markups, contractor OH & P, Contingency and Design and Services During Construction.*

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Estimated Payback Period for Installing Multiple-Stage Polymer Systems for Centrifuge Dewatering

	Polymer Consumption Reduction	
	10%	20%
Current Average Annual Polymer Costs	$800,000	$800,000
Average Annual Savings	$80,000	$160,000
Construction Costs (Polymer Skid Replacement Only	$645,000	$645,000
Payback (years)	8	4

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Summary and Conclusions

- Two- or three-stage polymer blending systems resulted in 10 to 25% polymer savings compared to existing one-stage system with cleaner centrate and minimal decrease in cake solids
- Reduction of polymer use was attributed to improved activation of the polymer solution
- Bench-scale jar testing (2 weeks); full-scale pilot testing (2 months)
- The installation of multiple-stage more effective polymer blending systems will result in:
  - 4- to 8-year payback period for FWHWRC
  - A safer work environment,
  - Improved polymer dose control and instrumentation, and
  - More operational flexibility

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Questions and Discussion

- Send questions to:

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Questions & Discussion

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