Polymer 101: Fundamentals of Flocculation
Thursday, June 25, 2020
1:00 – 2:30 PM ET
How to Participate Today

- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select “Use Telephone” and dial the conference (please remember long distance phone charges apply).

  - 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

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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

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

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

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

\[ ... - \text{CH}_2 - \text{CH} - [\text{CH}_2 - \text{CH}]_n - \text{CH}_2 - \text{CH} - ... \]

CO            CO CO
NH₂            CO  NH₂

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"

\[ n = \frac{10,000,000}{71} = 140,850 \]

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

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
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

Flocculation of Kaolin Suspension

Intrinsic viscosity of polymer solution

Subsidence rate, ml/min


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
Configuration of Emulsion Polymer

- Hydrocarbon Oil: 30%
- Polymer Gel: Polymer 40%
- Water 30%
- Specific gravity difference between hydrocarbon oil and polymer gels
- $d = 0.1 - 2 \, \mu m$

Storage of Emulsion Polymer

- Separation (stratification)
  - * Drum (Tote) Mixer
  - * Recirculation Pump
- Moisture Intrusion
  - * Drum (Tank) Dryer

- Separated Oil
- Settled Out Polymer Gels
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)

<table>
<thead>
<tr>
<th>PRAESTOL POLYMER GRADE</th>
<th>CATIONIC CHARGE</th>
<th>ACTIVE CONTENT (GRM/L)</th>
<th>DENSITY (GRM/L)</th>
<th>PRODUCT VISCOSITY (CP)</th>
<th>SOLUTION VISCOSITY 1% in DIEST WATER (CP)</th>
<th>SOLUTION VISCOSITY 1% NaCl/Brine (CP)</th>
<th>FREEZING POINT (°C)</th>
<th>EFFECTIVE pH RANGE</th>
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</thead>
<tbody>
<tr>
<td>K120L</td>
<td>Low</td>
<td>3%</td>
<td>1.03</td>
<td>&gt;4000</td>
<td>&gt;5000</td>
<td>&gt;2000</td>
<td>15</td>
<td>1.15</td>
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<tr>
<td>K105L</td>
<td>Low</td>
<td>3%</td>
<td>1.03</td>
<td>&gt;4000</td>
<td>&gt;3000</td>
<td>&gt;1000</td>
<td>15</td>
<td>1.15</td>
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<tr>
<td>K120L</td>
<td>Low-Medium</td>
<td>40%</td>
<td>1.03</td>
<td>&gt;4000</td>
<td>&gt;7000</td>
<td>&gt;500</td>
<td>15</td>
<td>1.10</td>
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<td>K22F-LX</td>
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<td>29%</td>
<td>1.03</td>
<td>&gt;4500</td>
<td>&gt;6000</td>
<td>&gt;400</td>
<td>15</td>
<td>1.15</td>
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<tr>
<td>K141L</td>
<td>Medium</td>
<td>40%</td>
<td>1.03</td>
<td>&gt;6000</td>
<td>&gt;7000</td>
<td>&gt;500</td>
<td>15</td>
<td>1.15</td>
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<tr>
<td>K122L</td>
<td>High</td>
<td>41%</td>
<td>1.04</td>
<td>&gt;6000</td>
<td>&gt;6000</td>
<td>&gt;300</td>
<td>15</td>
<td>1.05</td>
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<tr>
<td>K122L</td>
<td>High</td>
<td>41%</td>
<td>1.04</td>
<td>&gt;6000</td>
<td>&gt;6000</td>
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<td>1.05</td>
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<tr>
<td>K132L</td>
<td>High</td>
<td>35%</td>
<td>1.01</td>
<td>&gt;5000</td>
<td>&gt;8000</td>
<td>&gt;300</td>
<td>15</td>
<td>1.10</td>
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<tr>
<td>K133L</td>
<td>High</td>
<td>41%</td>
<td>1.05</td>
<td>&gt;8000</td>
<td>&gt;8000</td>
<td>&gt;150</td>
<td>15</td>
<td>1.13</td>
</tr>
</tbody>
</table>

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 °F may need water heater
  - Water over 100 °F may damage polymer chains
- Suspended Solids/ Turbidity/ TDS:
  - In-line strainer recommended
  - Caution in using reclaimed water for polymer mixing

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


Why High-Energy Mixing at Initial Wetting is Critical?

Polymer dissolution time, \( t_d \sim (\text{diameter})^2 \)

\[ t_d \sim 1 \text{ min} \]

\[ t_d \sim 100 \text{ min} \]

Initial high-energy mixing \( \rightarrow \) No fisheye formation \( \rightarrow \) Significantly shorter mixing time

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

**TYPICAL PROPERTIES**

- **Physical Form:** Clear to Milky White Liquid
- **Density:** TBD

**PREPARATION AND FEEDING**

CLARIFLOC WE-1181 is a single component cationic polymer that must be prediluted in water before use. In most cases, this product should not be applied neat. One method for dilution is adding the next polymer into the vortex of a mixed tank at a concentration between 0.15-1.0% polymer (0.9% is optimum) by weight. The polymer can also be injected through a number of commercially available systems that provide fine-mesh mechanical mixing. The feed systems use initial high energy mixing (1000 rpm) for a short time (5-30 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 6-16 hours.

“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
Two-Step Dilution with post-dilution primary mixing at high %, then post-dilution to feed

CLARIFLOC WE-1181 POLYMER

TYPICAL PROPERTIES

<table>
<thead>
<tr>
<th>Physical Form</th>
<th>Clear to Milky White Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cationicity</td>
<td>60%</td>
</tr>
<tr>
<td>Active Polymeramide</td>
<td>45.0 %</td>
</tr>
<tr>
<td>Precipitation Point</td>
<td>7 F. (14 C.)</td>
</tr>
<tr>
<td>Flash Point</td>
<td>&gt; 200 F. (&gt; 93 C.)</td>
</tr>
<tr>
<td>Density</td>
<td>TBD</td>
</tr>
</tbody>
</table>

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 mixing tank at a flow rate of 0.25-1.0% polymer (0.5% is optimum) by weight. The polymer can also be injected through numerous 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 add even good dispersion followed by low-energy mixing (<400 rpm) for a longer time (10-30 min). Polymer should be aged for 15-40 minutes for best results. Solution shelf life is 8-16 hours.

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

Two-Step Dilution facilitates Polymer Activation

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

Especially Important for Clarifier at WTP

Design 1

Primary Mixing

Polymer 1.0 gph

1.0%

Water 100 gph

Process

Post-Dilution

0.25% solution

0.25% solution

Process

Water 300 gph

4 x higher content of inverting surfactant*

to expedite polymer activation

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

To enable "inverting surfactant" to work properly, make polymer solution at high concentration.
Residence Time of low-energy mixing zone

Residence Time Effect of mix chamber

Volume of low-energy zone: \( V_L \)

\[ V_{LMM} = 3 \cdot V_{LM} \]

Effect of Residence Time in Mix Chamber

0.5% polymer solution viscosity, cP
Mechanical vs Hydraulic Mixing
Key is how to provide high mixing energy at initial wetting

**Mechanical Mixing**

- **Mean Shear Rate**
  \[ G = \left( \frac{P}{\mu V} \right)^{1/2} \]

  - \( G \): mean shear rate
  - \( P \): power delivered to fluid
  - \( \mu \): 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**
  \[ \text{Sum}(F) = \text{Sum}(\beta * m * V_{\text{out}}) - \text{Sum}(\beta * m * V_{\text{in}}) \]

  - \( F \): force, \( m \): mass
  - \( \beta \): momentum flux correction factor
  - \( V_{\text{in}} \): velocity in the x direction, zero in y
  - \( V_{\text{out}} \): \( V * \cos(\theta) \) in the x-direction
    \( V * \sin(\theta) \) in the y-direction
  - \( \theta \): 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
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

Thank You
Any Questions?
YKim@UGSIcorp.com
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)
Effect of Dilution Water Hardness

Soft water helps polymer chains to be fully extended

![Graph showing solution viscosity versus hardness](graph.png)


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

Especially Important for Clarifier at WTP

- Strips "oil" off the polymer surface
- Helps polymer get exposed to water quickly
- Breaks and disperses oil in micron size

Inverting (Breaker) Surfactant

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

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

![Diagram showing polymer inversion](diagram.png)
Mechanical vs Hydraulic (non-mechanical) Mixing

Flocculation - Bridging by Polymer Molecules

Extended cationic polymer molecule attracts negatively-charged suspended particles
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

![Image of water and polymer solution with labels for extremely low mixing, very high mixing, and extremely low mixing]

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George Tichenor, Ph.D.
Sr. Applications Scientist
SNF Inc.
Dewatering Optimization:
Practical Ways to Improve Performance -
Laboratory Testing

Topics

Laboratory polymer makedown
Polymer dosage calculation
Solids Consolidation Tests
  Pour Test
  Gravity Drainage Test (AKA Free Drainage or Buchner Funnel Test)
  Chopper Test
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

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

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

- \( P = 15 \text{ gpm} \)
- \( p = 0.50 \% \text{ polymer product} \)
- \( F = 300 \text{ gpm} \)
- \( f = 2.50\% \text{ sludge solids} \)

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

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

Simulation of filtration applications

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

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

Gravity Drainage Test

Simulation of filtration applications

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

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
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
Gravity Drainage Test

Sludge type:

Anaerobic digested sludge

<table>
<thead>
<tr>
<th></th>
<th>Feed (% Sol.)</th>
<th>Dosage (#/T)</th>
<th>Cake (% Sol.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-BPR</td>
<td>1.66</td>
<td>34.3</td>
<td>8.58</td>
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<tr>
<td>BPR</td>
<td>2.70</td>
<td>71.6</td>
<td>5.76</td>
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</table>

Gravity Drainage Test

Simulation of high-shear applications

Variables

- Polymer dosage, concentration and aging
- Polymer – sludge mixing
- Sludge throughput

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

Sludge type:
Anaerobic digested sludge

<table>
<thead>
<tr>
<th></th>
<th>Feed (% Sol)</th>
<th>Dosage (#/T)</th>
<th>Cake (% Sol.)</th>
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<tr>
<td>Non-BPR</td>
<td>1.66</td>
<td>47.0</td>
<td>7.53</td>
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<tr>
<td>BPR</td>
<td>2.70</td>
<td>74.1</td>
<td>5.06</td>
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</table>
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?
State-of-the-Practice in Biosolids/Polymer Blending for Biosolids Dewatering

David W. Oerke, P.E., BCEE
Jacobs Engineering
Denver, CO

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
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

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

<table>
<thead>
<tr>
<th>Process Equipment</th>
<th>Polymer Dosage (lb-act/dt)</th>
<th>Polymer Dosage ($/dt)</th>
<th>Bulk Polymer ($/mo.)</th>
<th>Cake Dryness (%)</th>
<th>Capture Rate (%)</th>
<th>Centrate TSS (mg/L)</th>
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</thead>
<tbody>
<tr>
<td>Dewatering Centrifuge</td>
<td>31.8</td>
<td>$64.13</td>
<td>$66,852/mo. X 12 = $802,208/year</td>
<td>23.6</td>
<td>99.4</td>
<td>191.0</td>
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<tr>
<td>Rotary Drum Thickener (RDT)</td>
<td>8.3</td>
<td>$20.77</td>
<td>$33,509/mo. X 12 = $402,112/year</td>
<td>7.5</td>
<td>99.0</td>
<td>209.1</td>
</tr>
</tbody>
</table>

Total $1,204,320/year

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
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)

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

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

Two-Stage Mixing → Significant Performance Increase in Polymer Activation in Full-Scale Testing at Several WWTPs
Existing and Pilot Polymer Blending Units

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>SNF FloQuip</th>
<th>UGSi Chemical Feed Solutions</th>
<th>ProMinent Fluid Controls</th>
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</thead>
<tbody>
<tr>
<td>Skid</td>
<td>Existing Centrifuge Skid</td>
<td>Pilot 1 Skid</td>
<td>Pilot 2 Skid</td>
</tr>
<tr>
<td>Model</td>
<td>EA- Series (EA70-P)</td>
<td>PolyBlend M-Series</td>
<td>ProMix L-Series Demo Skid</td>
</tr>
<tr>
<td>Capacity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polymer Feed Rate</td>
<td>0.03-0.57 gpm</td>
<td>0.5 gpm</td>
<td>unknown</td>
</tr>
<tr>
<td>Dilution W3 Flow Rate</td>
<td>30 – 70 gpm</td>
<td>20 gpm</td>
<td>60 gpm</td>
</tr>
<tr>
<td>Post Dilution W3 Flow Rate</td>
<td>N/A</td>
<td>20 gpm</td>
<td>60 gpm</td>
</tr>
<tr>
<td>Polymer Sol. Conc. Range</td>
<td>0.1 – 1.0%, Speed Dial</td>
<td>0.1 – 2.5%, 0.01% increments</td>
<td>0.1 – 1.0%, 0.01% increments</td>
</tr>
<tr>
<td>Mixing Chamber</td>
<td>Goulds centrifugal pump used in one-stage mixing chamber</td>
<td>UGSi patented Magnum two-stage multi-zone mixing, with clear mixing chamber</td>
<td>Large three-stage multi-zone mixing</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Test</th>
<th>Polymer Blending Unit &amp; Centrifuge</th>
<th>Average Polymer Dose (lb-act/dt)</th>
<th>Centrifuge Sludge Feed Flow Range (gpm)</th>
<th>Average Dry Cake Solids, TS (%)</th>
<th>Average Centrate TSS (mg/L)</th>
<th>Average Percent Capture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot 1</td>
<td>UGSi PolyBlend Centrifuge #10</td>
<td>25.7</td>
<td>100 - 180</td>
<td>20.4</td>
<td>184.4</td>
<td>99.5 (± 0.1)</td>
</tr>
<tr>
<td></td>
<td>SNF FloQuio Centrifuge #5</td>
<td>33.9</td>
<td>100 - 200</td>
<td>21.5</td>
<td>193.5</td>
<td>99.5 (± 0.1)</td>
</tr>
<tr>
<td>Pilot 2</td>
<td>ProMinent Centrifuge #10</td>
<td>28.0</td>
<td>100 - 180</td>
<td>20.1</td>
<td>190.6</td>
<td>99.5 (± 0.1)</td>
</tr>
<tr>
<td></td>
<td>SNF FloQuio Centrifuge #5</td>
<td>31.3</td>
<td>100 - 200</td>
<td>21.7</td>
<td>183.0</td>
<td>99.5 (± 0.1)</td>
</tr>
</tbody>
</table>
Conclusions: Two-Stage Pilot Equipment Versus Existing One-Stage Polymer Blending Equipment

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

Cent #5: 31.6 lb/dT at 0.75%

Cent #10: 26 lb/dT at 0.5%

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

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

Inputs Values:
- TS before the centrifuge
- Flow before the centrifuge
- TSS at the centrate, DS at the dry cake chute

Output values:
- Polymer setpoint
- Torque setpoint
- Biosolids feed flow setpoint

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
**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:*

---

**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*
Estimated Construction Cost For All Polymer Improvements

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDT Biological Solids Thickening Polymer Improvements*</td>
<td>$886,000</td>
</tr>
<tr>
<td>Centrifuge Dewatering Polymer Improvements*</td>
<td>$2,211,000</td>
</tr>
<tr>
<td>Chemical Thickening Polymer Improvements*</td>
<td>$345,000</td>
</tr>
<tr>
<td><strong>Total Construction</strong>*</td>
<td>$3,442,000</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th></th>
<th>Polymer Consumption Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Current Average Annual Polymer Costs</td>
<td>$800,000</td>
</tr>
<tr>
<td>Average Annual Savings</td>
<td>$80,000</td>
</tr>
<tr>
<td>Construction Costs (Polymer Skid Replacement Only)</td>
<td>$645,000</td>
</tr>
<tr>
<td>Payback (years)</td>
<td>8</td>
</tr>
</tbody>
</table>
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.

Questions and Discussion

- Send questions to:

  David W. Oerke, P.E. BCCEE
  Jacobs Engineering
  720-544-1659 (cell)
Questions & Discussion