Optimizing Polymer Mixing/Activation Improves Sludge Dewatering: Case Studies

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Annual Average Dewatering Cost (2011-2014) = $3.7M/yr

Polymer Cost - Average $1.2 M/yr

K. Tagney and R. Gupta, Reducing Dewatering Costs through Optimization Program, 2017 WEFTEC.
Presentation Overview

1. **Science of Polymer Activation**
   - Viscosity as an indicator of polymer solution quality
   - Effect of dilution water
   - Two-stage mixing for dry and emulsion polymers
   - Residence time sufficient for polymer uncoiling/dissolution
   - Weissenberg effect in dry polymer mixing

2. **Case Studies**
   - Water Treatment Plant, PA – emulsion polymer
   - Wastewater Treatment Plant, CA – dry polymer

3. **Aging Issue in Dry Polymer Activation**
Three Forms of Polymer Solutions

Neat polymer

Fisheyes due to poor initial wetting

Ideal polymer chains by two-stage mixing

Broken polymer chains by excessive mixing
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

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

<table>
<thead>
<tr>
<th>PRAESTOL POLYMER GRADE</th>
<th>CATIONIC CHARGE</th>
<th>ACTIVE CONTENT</th>
<th>DENSITY (GR/ML)</th>
<th>PRODUCT VISCOSITY (CP)</th>
<th>SOLUTION VISCOSITY 1% IN DIST. WATER(^{(1)}) (CP)</th>
<th>SOLUTION VISCOSITY 1.0% in 10% NaCl-Brine (^{(2)}) (CP)</th>
<th>FREEZING POINT (°C)</th>
<th>EFFECTIVE pH RANGE</th>
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<tbody>
<tr>
<td>K105L</td>
<td>Low</td>
<td>30%</td>
<td>1.04</td>
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<td>&gt;2000</td>
<td>-15</td>
<td>1-10</td>
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<td>K110FL</td>
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<td>1.03</td>
<td>&lt;4000</td>
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<td>1.03</td>
<td>&lt;4000</td>
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<td>1.03</td>
<td>&lt;4500</td>
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<tr>
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<td>1.03</td>
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<tr>
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<td><strong>&gt;9000</strong></td>
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<td>1.04</td>
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<tr>
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<td>&gt;8000</td>
<td>&gt;150</td>
<td>-15</td>
<td>1-13</td>
</tr>
</tbody>
</table>

*UGSI Chemical Feed Solutions*
Effect of Dilution Water Quality

**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 ppm
- Caution in using *recycled water* for polymer mixing
  + Serious 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:**
- In-line strainer recommended
- Caution in using recycled water for polymer mixing

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*David Oerke, 20% less polymer with warm water, 40% more polymer with 140F sludge, Residuals and Biosolids (2014)*
Effect of Dilution Water Chlorine Content

When reclaimed water used for polymer mixing, chlorine < 3 mg/L
Polymer Activation (Mixing, Dissolution)

(I) Initial Wetting (Inversion)
Sticky layer formed
High-energy mixing -> No fisheyes

Most Critical Stage

(II) Dissolution
Reptation* or Uncoiling
Low-energy mixing -> No damage to polymer

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

“Discrete” Two-Stage Mixing - discrete means “separation of high and low energy mixing zones”
One-Stage vs Two-Stage Mixer (Emulsion Polymer)

1- stage mixer

2- stage mixer

G-value, mean shear rate (sec⁻¹)

1,700

1,100

4,000

Dividing Baffle
One-Stage Mixing vs. Two-Stage Mixing

Two-stage mixing → significant increase of polymer solution efficiency

Viscosity of 0.5% Emulsion Polymer Solution, cP

- Anionic Polymer: 37% increase
  - 1-stage mixer: 226
  - 2-stage mixer: 310

- Cationic Polymer: 22% increase
  - 1-stage mixer: 427
  - 2-stage mixer: 523
**Residence Time** (in mix chamber)

Sufficient residence time of low-energy mixing zone is required for complete polymer dissolution

\[ t = \frac{V}{v} \]

Residence time \((t)\) in flocculating basin: \(Gt\)-value

\(Gt\)-value = mean shear rate \(\times\) residence time

Contact time \((T)\) in clear well design: \(CT\) calc

\(CT\) calc = residual chlorine concentration \(\times\) contact time

Residence time \((t)\) in polymer activation

Second stage of polymer activation – “uncoiling” of long chain polymer molecules requires more time under low energy mixing than high energy first stage mixing
Effect of Residence Time on Polymer Activation

Volume of low-energy zone: $V_L$

$V_{L,MM} = 3 \times V_{L,M}$

Effect of Residence Time of Mix Chamber
(0.5% polymer solution viscosity, cP)

M, 0.5 gal

MIM, 1.0 gal

Effect of Residence Time on Polymer Activation
16-mgd Water Plant, PA with two BFP (2-M)

Existing Polymer System
Siemens M1200-D10AA (2011)

New Polymer System
UGSI MM1200-D10AA (2016)
Side-by-Side Trial from Feb to May 2016

Polymer savings 30% - 35%

Sludge throughput increased by 10%
Polymer science dictates the most effective way of activating polymers—**Your** activation equipment should follow:

- High Energy at MOIW
- Transition to low energy "quiescent zone"
- Adequate Residence time
- Fully activated polymer solution at desired concentration
PolyBlend® Dry Polymer System

Two-Stage Mixing

First Stage
High Energy Mixing
(3,450 rpm, < 0.5 sec)

Second Stage
Low Energy Mixing
(60 rpm, 20 min)

DD4 Disperser
Mix and Hold Tanks

Polymer Solution Storage/Holding
(no mixing)
First-Stage of Dry Polymer Mixing: High Energy Initial Wetting

Very High-Energy Mixing for Short Time

\[ G = 15,000 \text{ sec}^{-1} \]

3,450 rpm for < 0.5 sec

Disperses Individual Polymer Particles

* No Fisheye Formation

* Shorter Mixing Time in Next Stage
Why Initial High-Energy Mixing is So Critical?

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

Assume $t_s \rightarrow 1 \text{ min}$

$t_s \rightarrow 100 \text{ min}$

Initial high-energy mixing $\rightarrow$ No fisheye formation $\rightarrow$ Significantly short mixing time

Mixing Tank for Dissolution of Dry Polymer

Patented Hollow-Wing Impeller

- No Weissenberg Effect

Large Impeller, **70% of tank diameter**

- Uniform Mixing Energy

Low RPM, 60 rpm

- Low-intensity Mixing
- Minimize Damage to Polymer Chain

Shorter Mixing Time – Due to **high energy DD4**

- 20 - 30 min for Cationic Polymer
- 30 - 40 min for Anionic Polymer
- Minimize Damage to Polymer Chain
Weissenberg Effect in Polymer Mixing

* Polymer solution exceeding “critical concentration” climbs up mixing shaft
* Extremely non-uniform mixing
* Critical factor for “conventional” polymer mix tank → max 0.2% limit for HMW polymer

![Image](image_url)

- Water (Newtonian)
- Polymer Solution (Non-Newtonian, Pseudoplastic)
Notice polymer solution is “climbing” up the mixer shaft (30 min after mixing (Nalco TX13182): 0.25%, 0.50%)
Polymer Mixing Tank With No Weissenberg Effect

Eye of impeller
Hollow-wing impeller
PVC sleeve around mixer shaft separates mixer shaft from polymer solution
Rotating shaft

PVC sleeve prevents Weissenburg effect at high concentration, up to 1.0%

Why high conc. solution?
* Smaller tank size
* Longer shelf life solution

Impeller / tank diameter > 0.7
Cationic Polymer Solution @ 0.75%
Case Study: Dry Polymer Mixing System
Fairfield-Suisun Sewer District, CA

- Solano County, CA, 40 miles North San Francisco
- Design capacity: 24 MGD tertiary treatment/UV
- Population served: 135,000
- Polymer use for dewatering (screw press) and thickening (GBT)

Problems with existing polymer system
- Struggled to make proper polymer solution
- Polymer performance inconsistent
- Frequent maintenance issues

FKC screw press runs at average 70 gpm of sludge (2% solids content)
Pilot Testing with Two Polymer Mix Equipment

**Existing Polymer System**
- Initial wetting: air blower → wetting head
- Mixing: two (2) 4,600 gal mix/age tanks
- 1 hour mixing and 4 - 8 hour aging time

**UGSI PolyBlend Dry Polymer Demo System**
- Initial wetting: high-energy mechanical mixing
- Mixing: two (2) 360 gal mix tanks
- 20 minute mixing, 10+ minute transfer time
Newly Installed Dry Polymer System

Old: Two 4,600 gal mixing/aging tanks
  * 60 min mixing, 2-4 hour aging
New: Two 1,000 gal mixing tanks
  * 30 min mixing, 15 min holding
FSSD Installed New PolyBlend® DP2000

Performance Data in 2016

FSSD saved 42% on Screw Press Polymer in 2016 despite an increase in solids throughput by 18%
AGING “accelerated maturing” by initial high-energy wetting

Very High-Intensity Mixing for Short Time

\[ G = 15,000 \text{ sec}^{-1} @ 3,450 \text{ rpm} \]
Residence time < 0.5 sec

Disperses Individual Polymer Particles

* No Fisheye Formation
* Complete dissolution in 20 - 30 min mixing
* Aging – reduced or eliminated
How Much Aging is Required for Dry Polymer?

Minimum aging required for well-designed equipment

Aging – heavily depends on Polymer, Mixing, Water

Aging may help:
* Very high molecular-weight, low charge (nonionic) polymers, or
* Low energy mixing at initial wetting stage

Aging does not help:
* Medium high molecular-weight, high charge polymers, or
* Very high energy mixing at initial wetting stage

Aging may hurt:
* Reclaimed water for polymer mixing, or
* Low concentration of polymer solution

Aging must be reconsidered when reclaimed water is used
Thank You
Any Questions?