Maximizing Polymer Value for Improved Sludge Dewatering

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Presentation Overview

- Characteristics of Polymer
- Effect of Dilution Water Chemistry
- Effect of Mixing Energy/Strategy
  - Two-stage Primary Mixing
  - Primary Mixing then Post-Dilution
- Case Study at Fairfield WWTP
Coagulation and Flocculation

**Coagulation**
- Double-layer compression (charge neutralization)
- Enmeshment (sweep coagulation)
  - Clay suspension + Ferric chloride (40 – 120 mg/L)

**Flocculation**
- Polymer Bridging
  - Clay suspension + Ferric chloride + Polymer (< 1.0 mg/L)
Flocculation - Bridging by Polymer Molecules

Extended cationic polymer molecule attracts negatively-charged suspended particles.

How to prevent long-chain polymer molecules from being damaged?
Polymer Structure

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

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

\begin{align*}
\text{CO} & \quad \text{CO} & \quad \text{CO} \\
\text{NH}_2 & \quad \text{NH}_2 & \quad \text{NH}_2
\end{align*}

Most polymers in water industry are acrylamide-based.

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

\[
\begin{align*}
n & = \frac{10,000,000}{71} \\
& = 140,850 \\
\text{(mol. wt. of monomer, acrylamide} & = 71)\end{align*}
\]
Measure of Polymer Activation - Polymer Solution Viscosity

Effect of Dilution Water Quality on Polymer Activation

**Ionic strength (Hardness):** multi-valent ions; adverse effect
- Soft water helps polymer molecules fully-extend faster
- Hardness over 400 ppm may need softener

**Oxidizer (chlorine):** detrimental to polymer chains
- Should be less than 3 ppm

**Temperature**: higher temperature, better polymer activation
- In-line water heater for water lower than 40 °F
- Water over 100 °F may damage polymer chains

**Suspended solids:** strainer recommended if > 10 ppm

**pH:** negligible effect within pH 3 - 10

*David Oerke (CH2M), et al., 2014 Biosolids Conf. - 20% less polymer with warm water, 40% more polymer with 140°F sludge*
Effect of Chlorine (Oxidizing Chemical)

When effluent is used for polymer mixing, chlorine should be < 3 mg/L
Polymer Activation (Mixing, Dissolution)

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

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

Mixing Effect on Polymer Activation

Viscosity of polymer solution (prepared in 600 mL beakers)
- Beakers 1, 2: one-stage mixing
- Beaker 3: two-stage mixing

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

* High energy first: prevent fisheye formation
* Low energy followed: minimize polymer damage
Development of Two-stage Mixer

1- stage mixer (EC)

2- stage mixer (PB)

G-value, mean shear rate (sec\(^{-1}\))
Mixing Effect on Polymer Activation

Two-stage mixing → significant increase in polymer solution viscosity

Viscosity of 0.5% Emulsion Polymer Solution, cP

1-stage mixer  | 2-stage mixer
---|---
Anionic Polymer | 226 | 310  | 27% up
Cationic Polymer | 427 | 523  | 18% up

PolyBlend® Technology
Why Primary Mixing followed by Post-Dilution?
Inverting Surfactant helps to invert w/o emulsion to o/w emulsion

- Stabilizing surfactant
- Inverting (breaker) surfactant*

To maximize the value of Inverting Surfactant,
* 0.75% - 1.0% primary mixing
* 0.25% - 0.5% secondary mixing (dilution)

\[ d = 0.1 - 2 \mu m \]

\* AWWA Standard for Polyacrylamide (ANSI-AWWA B453-06), 11, 2006
How to Maximize the Value of Inverting Surfactant?

Primary mixing at high % + Post-dilution at feed %

**Ideal Design**

- Polymer 1 gph
- Water 100 gph

- Primary Mixing
  - 1.0%

- Post-Dilution
  - Water 100 gph

- 0.5% solution
PolyBlend Polymer Mixing Systems

Two-stage mixing in mix chamber
Primary mixing followed by post-dilution
Dry Polymer Mixing System

Two-stage Mixing

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

Low Energy Mixing
(60 rpm, 20 min)
(0.5% - 0.75%)

Post-dilution
(0.1% - 0.2%)

Solution Feed

Initial Wetting

Mixing Tank
Dry Disperser (DD4) for Initial Wetting

Very High-Intensity Mixing for Short Time

\[ G = 15,000 \text{ /sec} \]
\[ @ \ 3,450 \text{ rpm} \]
\[ \text{for < 0.5 sec} \]

Disperses Individual Polymer Particles

* No Fisheye Formation
* Shorter Mixing Time in Next Stage
How to Reduce Mixing/Aging Time in Polymer Mixing?
Initial high-energy mixing is critical

Polymer dissolution time, \( t_s \sim (\text{diameter})^2 \) \hspace{1cm} \text{Tanaka (1979)*}

Assume \( t_s \rightarrow 1 \text{ min} \)

\( t_s \rightarrow 100 \text{ min} \)

Initial high-energy mixing (DD4) \( \rightarrow \) No fisheye formation \( \rightarrow \) Significantly shorter mixing time \( \rightarrow \) Minimum damage to polymer structure \( \rightarrow \) Better quality polymer solution \( \rightarrow \) Less Polymer Usage

Mixing Tank for Dissolution of Dry Polymer

Patented Hollow-Wing Impeller

- No Weissenberg Effect

Large Impeller, $d/D > 0.7$

- Uniform Mixing Energy

Low RPM, 60 rpm

- Low-intensity Mixing

- Minimize Damage to Polymer Chain

Shorter Mixing Time – Due to DD4

- 20 Minutes for Cationic Polymer

- 30 Minutes for Anionic Polymer

- Minimize Damage to Polymer Chain
Weissenberg Effect

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

Water  
(Newtonian)  

Polymer Solution  
(Non-Newtonian, Pseudoplastic)  

extremely low mixing  
very high mixing  
extremely low mixing
PolyBlend® DP Series Tank Mixing

- Impeller diameter/ tank diameter > 0.7
- Cationic Polymer Solution @ 0.75%

- PVC sleeve around mixer shaft prevents Weissenburg effect

Eye of impeller
Hollow-bladed impeller

PVC sleeve around mixer shaft
Fairfield-Suisan, CA - Sewer District

- Solano County, CA, 40 miles North San Francisco
- Design capacity: 24 MGD
- Population served: 135,000
- Tertiary treatment/ UV disinfection
- 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
Pilot Testing with Two Polymer Mix Equipment

Existing Polymer System
• Initial wetting: educator-type hydraulic mixing
• Mixing: two (2) > 3,000 gal mix/age tanks

UGSI PolyBlend Dry Polymer System
• Initial wetting: high-energy mechanical mixing
• Mixing: two (2) 360 gal mix tanks with hollow-blade impeller
Fairfield-Suisan SD – Pilot Test Results

- **Dewatering by Screw Press** *(3/21 – 4/21)*
  - Less polymer consumption
    * Daily usage from 255 lbs to 200 lbs
    * 22% polymer savings
- **Better** cake solids
  * 14% - 16% to average 16.4%

- **Thickening by GBT** *(4/24 – 5/23)*
  - Less polymer consumption
    - Daily usage from 29 lbs to 20 lbs
Various Forms of Polymer Solution

- Neat polymer
- Fisheyes due to poor initial wetting
- Ideal polymer chains by two-stage mixing
- Broken polymer chains by longer mixing time
Thank You

Please contact Yong Kim with any questions

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How Much Aging Time is Required for Dry Polymer?

PolyBlend® DD4/DP-series do not need additional aging

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