LABORATORY JAR TESTING

PRESENTED TO
MICHIGAN WATER ENVIRONMENT ASSOCIATION
EAST LANSING, MI
APRIL 29, 2015

BY GEORGE TICHENOR, PH.D.
SNF/POLYDYNE INC.
TOPICS

• POLYMER / SUBSTRATE INTERACTION
• SOLID – LIQUID SEPARATION TESTS
  • CLARIFICATION
  • SOLIDS THICKENING & DEWATERING
• POLYMER MAKEDOWN
## POLYMER SELECTION

What are concerns and solutions?

<table>
<thead>
<tr>
<th>CRITERION</th>
<th>CONCERN</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUBSTRATE</td>
<td>Polymer must be properly selected depending on</td>
<td>Appropriately test complete range.</td>
</tr>
<tr>
<td>NATURE</td>
<td>substrate and application.</td>
<td></td>
</tr>
<tr>
<td>MAKEUP</td>
<td>Product must be fully dissolved (inverted) for best</td>
<td>Check make-down for full activity.</td>
</tr>
<tr>
<td></td>
<td>performance.</td>
<td></td>
</tr>
</tbody>
</table>
# POLYMER SELECTION

What are concerns and solutions?

<table>
<thead>
<tr>
<th>CRITERION</th>
<th>CONCERN</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUBSTRATE NATURE</td>
<td>Polymer must be properly selected depending on substrate and application.</td>
<td>Appropriately test complete range.</td>
</tr>
<tr>
<td>MAKEUP</td>
<td>Product must be fully dissolved (inverted) for best performance.</td>
<td>Check make-down for full activity.</td>
</tr>
</tbody>
</table>
POLYMER / SUBSTRATE INTERACTION: WHY SO MANY PRODUCTS?
Different applications → different characteristics

- NATURE OF THE SUBSTRATE
- DETERMINES CHARGE
- NATURE OF THE APPLICATION
- DETERMINES MW, STRUCTURE
POLYMER / SUBSTRATE INTERACTION: EFFECT OF CHARGE
POLYMER / SUBSTRATE INTERACTION: CHARGE AND APPLICATIONS

- Dewatering paper sludge
- Dewatering primary sludge
- Dewatering mixed sludge
- Dewatering digested sludge
- Raw water clarification
- Drinking water
- General industrial effluents
- Sugar applications
- Coal washing
- Red mud alumina
- Dewatering alkaline sludge

100% CATIONIC  0% NON-IONIC  100% ANIONIC
**NATURE OF THE SUBSTRATE**

What impacts the polymer choice, dosage?

<table>
<thead>
<tr>
<th>Suspended Solids</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry</td>
<td>pH</td>
</tr>
<tr>
<td>Particle Size</td>
<td>Hardness</td>
</tr>
<tr>
<td>Concentration</td>
<td>Conductivity</td>
</tr>
<tr>
<td>Density</td>
<td></td>
</tr>
<tr>
<td>Microbial Population</td>
<td>Added Chemicals</td>
</tr>
<tr>
<td>Shape</td>
<td>Oxidants</td>
</tr>
<tr>
<td></td>
<td>Defoamers</td>
</tr>
<tr>
<td></td>
<td>Coagulants</td>
</tr>
</tbody>
</table>
POLYMER / SUBSTRATE INTERACTION: EFFECT OF MOLECULAR WEIGHT

- SETTLING APPLICATIONS
  - HIGH MW → FAST
  - LOW MW → MORE COMPLETE

- THICKENING/DEWATERING APPLICATIONS
  - FILTRATION
    - LOW MW → GOOD PERFORMANCE
    - HIGH MW → BLINDING
  - CENTRIFUGE
    - HIGH MW, STRUCTURE → GOOD PERFORMANCE
    - LOW MW → SHEARED FLOC
POLYDYNE FLOCCULANTS

POLYMER / SUBSTRATE INTERACTION:
EFFECT OF STRUCTURE

LINEAR

- Low dosage
- Wide range of molecular weights

DRAWBACKS
- Low floc strength
- Overdosing possible

ADVANTAGES
- High floc stability
- Very good drainage
- Better cake dryness

STRUCTURED

- High dosage

POLYMER / SUBSTRATE INTERACTION:
EFFECT OF STRUCTURE

LINEAR

- Low dosage
- Wide range of molecular weights

DRAWBACKS
- Low floc strength
- Overdosing possible

ADVANTAGES
- High floc stability
- Very good drainage
- Better cake dryness

STRUCTURED

- High dosage
## TEST SELECTION

Which test for which application?

**CLARIFICATION**

- LOW SOLIDS: JAR TEST
- HIGH SOLIDS: CYLINDER SETTLING
- EMULSION BREAKING
- DISSOLVED AIR FLOTATION

**SOLIDS THICKENING/DEWATERING**

- POUR TEST
- GRAVITY DRAINAGE (BUCHNER FUNNEL)
- BAROID CELL
- CHOPPER
- CAPILLARY SUCTION TIMER
- VACUUM FILTER LEAF
CLARIFICATION: GANG STIRRER (JAR TESTER)
SOLIDS THICKENING / DEWATERING:

GRAVITY DRAINAGE TEST

(BUCHNER FUNNEL TEST)
SOLIDS THICKENING / DEWATERING: CHOPPER (BLENDER)
POLYDYNE FLOCCULANTS

SOLIDS THICKENING / DEWATERING: CAPILLARY SUCTION TIMER
How do I select a polymer program?

PHASE 1. GENERAL SCREENING
(PRIOR KNOWLEDGE, JAR OR POUR TESTS)
– INCUMBENT OR BLANK
– COAGULANT
– MODERATE CHARGE ANIONIC FLOCCULANT
– LOW CHARGE ANIONIC FLOCCULANT
– LOW CHARGE CATIONIC FLOCCULANT
– MODERATE CHARGE CATIONIC FLOCCULANT
– pH

PHASE 2. PRODUCTS SURROUNDING BEST GENERAL PROGRAM
(USING APPROPRIATE TEST)
### COAGULANTS AND FLOCCULANTS

**What makes them different?**

<table>
<thead>
<tr>
<th>COAGULANTS</th>
<th>FLOCCULANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATIONIC</td>
<td>ANY CHARGE TYPE</td>
</tr>
<tr>
<td>HIGH CHARGE</td>
<td>0 TO 100% CHARGE</td>
</tr>
<tr>
<td>LOW MOLECULAR WT.</td>
<td>MODERATE TO HIGH MW</td>
</tr>
<tr>
<td>SOLUTION FORM</td>
<td>VARIOUS FORMS</td>
</tr>
<tr>
<td>METAL SALT OR ORGANIC</td>
<td>ORGANIC</td>
</tr>
</tbody>
</table>
(ORGANIC) COAGULANTS

What are the chemistries?

- POLYQUATERNARY AMMONIUM SALTS
  - POLYDADMAC
  

\[
\text{CH}_2\text{-CH-CH-CH}_2^+ \\
\text{CH}_2 \quad \text{CH}_2 \\
\text{N}^+ \quad \text{Cl}^- \\
\text{H}_3\text{C} \quad \text{CH}_3
\]

- POLYAMINE

\[
\text{-CH}_2\text{-CH-CH}_2\text{-N}^+\text{(CH}_3\text{)}_2^- \\
\quad \text{Cl}^- \\
\quad \text{OH}
\]
FLOCCULANTS

What are the chemistries?

Homopolymer of acrylamide (nonionic)

\[ n \text{CH}_2=\text{CH} \quad \rightarrow \quad (\text{CH}_2-\text{CH-CH}_2-\text{CH})_{n/2} \]

\[ \quad \text{C}=\text{O} \quad \text{C}=\text{O} \quad \text{C}=\text{O} \]

\[ \quad \text{NH}_2 \quad \text{NH}_2 \quad \text{NH}_2 \]

Acrylamide \hspace{1cm} Polyacrylamide

\[ n = 15,000 \text{ to } 350,000 \]
FLOCCULANTS
What are the chemistries?

ANIONIC (COPOLYMERS OF ACRYLAMIDE AND)

\[-(CH_2CH-)_n \quad -(CH_2CH-)_n\]

\[O = CO^-Na^+ \quad O = CNHCH_2CH_2SO_3^-Na^+\]

(NON-ACRYLAMIDE BASED)

\[-(CH_2CH_2N)_n\]

\[S = CS^-Na^+\]

CATIONIC (COPOLYMERS OF ACRYLAMIDE AND)

\[-(CH_2CH-)_n \quad -(CH_2CH-)_n\]

\[O = COCH_2CH_2N^+(CH_3)_3 \quad O = CNHCH_2N(CH_3)_2\]
# POLYMER SELECTION

What are concerns and solutions?

<table>
<thead>
<tr>
<th>CRITERION</th>
<th>CONCERN</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUBSTRATE NATURE</td>
<td>Polymer must be properly selected depending on substrate and application.</td>
<td>Appropriately test complete range.</td>
</tr>
<tr>
<td>MAKEUP</td>
<td>Product must be fully dissolved (inverted) for best performance.</td>
<td>Check make-down for full activity.</td>
</tr>
</tbody>
</table>
POLYMER MAKEDOWN

What are the factors?

- DISSOLUTION
- STABILITY OF THE MADE-DOWN SOLUTION
## COAGULANT / FLOCCULANT MAKEDOWN

How do we dissolve them?

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CONC.</th>
<th>LAB</th>
<th>PLANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLUTION</td>
<td>5 - 10%</td>
<td>SHAKE OR STIR</td>
<td>IN-LINE OR MIX TANK</td>
</tr>
<tr>
<td>POWDER</td>
<td>0.1 - 0.5%</td>
<td>DISPERSE &amp; STIR 15-30 MIN.</td>
<td>DISPERSE &amp; MIX 15-120 MIN.</td>
</tr>
<tr>
<td>EMULSION</td>
<td>0.2 - 1.0</td>
<td>DISPERSE &amp; STIR 10-15 MIN.</td>
<td>DISPERSE &amp; MIX* 30-45 MIN.</td>
</tr>
</tbody>
</table>

* DISPERSE AT HIGH SHEAR & MIX AT LOW SHEAR
EMULSION POLYMERS

WATER + POLYMER

Oil

Stabilizing surfactant

Inverting surfactant

WATER + POLYMER
EMULSION INVERSION
LABORATORY EMULSION MAKEDOWN

What are the proper techniques?

- **GOOD DISPERSION**
  - VARIABLE SPEED MIXER/PROP, JIFFY MIX BLADE
  - BRAUN MIXER *(5 SEC *ONLY!*)
  - JAR TESTER
  - *(MAGNETIC MIXER)*

- **POOR DISPERSION**
  - SEALED JAR/SHAKING

*AGE THE MAKEDOWN BEFORE USE!*
EMULSION MAKEDOWN AGING

Inverted and aged properly

Inverted with no aging
FLOCCULANT SOLUTIONS

What are the aspects of stability?

- CHARGE
- CHAIN LENGTH (MW)
FLOCCULANT SOLUTIONS

What affects *charge* stability?

- **ANIONIC COPOLYMERS**
  - *(Stable)*

- **CATIONIC COPOLYMERS**
  - pH
  - Hardness

- **MANNICH POLYMERS**
  - Concentration
CATIONIC POLYACRYLAMIDES
Polymer charge loss over time: pH

![Graph showing polymer charge loss over time at different pH levels (pH 3.8, pH 6, pH 7, pH 8, pH 9, pH 10).]
In hard water: TH = 350 mg/l CaCO₃, pH solution = 8.0

Water released (ml)

Time (s)

- FO 4350 after 3 hours in soft water
- FO 4350 after 1 hour in hard water
- FO 4350 after 2 hours in hard water
- FO 4350 after 3 hours in hard water
FLOCCULANT SOLUTIONS

What effects $m_w$ stability?

ACRYLIC MW’s REDUCED BY

- SHEAR
- HYPOCHLORITE, CHLORINE
  - IMPACTS AT 0.5 PPM LEVEL
- FERROUS ION
  - IMPACTS AT PPM LEVEL
  - OXIDATION TO FERRIC ELIMINATES EFFECT
## ADDING POLYMER TO SUBSTRATE

What are concerns and solutions?

<table>
<thead>
<tr>
<th>CRITERION</th>
<th>CONCERN</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIXING</td>
<td>The waste should be well-flocculated at the right location.</td>
<td>Adjust in-line mixing, change feed points or post-dilute polymer.</td>
</tr>
<tr>
<td>FLOC SIZE</td>
<td>Too small floc drains slowly. Too large floc retains water.</td>
<td>Consider floc size when choosing mw. Adjust mixing.</td>
</tr>
<tr>
<td>STABILITY</td>
<td>Floc must be stable to shear. Too much shear inc. polymer demand.</td>
<td>Inc. poly feed conc. mw or structure to maintain floc strength.</td>
</tr>
</tbody>
</table>
TAKEAWAYS

• Every substrate will have an optimum polymer program and dosage.

• Consider the substrate and what you’re doing to it.

• Take care that the polymer is made down and aged properly and added to the substrate optimally.
QUESTIONS?

Polydyne contact:
Eric Butler
Ebutler@polydyneinc.com
(313) 506-5755 (cell)
THANK YOU!