Using PACs to Achieve Low-Level Phosphorus Requirements

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Session M
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Introduction to Poly-Aluminum Chlorides (PACs)
What are PACs?

• **Poly-Aluminum Chloride**
  - Aluminum chloride with added “basicity” to reduce alkalinity consumption
  - Polymeric structure of aluminum; does not necessarily contain added polymers

• **Basicity can range up to 80%**
  - Greater than 80% indicative of Aluminum Chlorohydrate (ACH)
  - 0% basicity = aluminum chloride (AlCl₃)

• **PACs refer to broad family of products**

• **Chemical Formula: Alₙ(OH)ₓCl₃n-x**
What are PACs?

- PAC’s most prevalent in drinking water treatment
  - Developed for turbidity and TOC removal and to reduce need for pH control

- Most PAC’s not effective for phosphorus removal

- Developed a PAC product which demonstrated high rates of P removal
  - Mid-basicity PAC
  - 9% Al vs 4.5% Al with Alum
Fe/Al P Removal Mechanism

- **Phosphate removal mechanism**

  - \[
  \text{Fe}^{3+}/\text{Al}^{3+} + 3\text{H}_2\text{O} \rightarrow \text{Fe}/\text{Al(OH)}_3 + 3\text{H}^+
  \]

  - \[
  \text{Fe}/\text{Al(OH)}_3 + \text{H}_2\text{PO}_4^- \rightarrow \text{Fe}/\text{Al(OH)}_2\cdot\text{HPO}_4^- + \text{H}_2\text{O}
  \]

- **Each Fe}^{3+} or Al}^{3+} produces 3 parts of H}^+ (acid)**
PAC P Removal Mechanism

- Phosphate removal mechanism for PAC’s

  - \([-\text{Al(OH)}-\]^{2+} + 2\text{H}_2\text{O} \rightarrow \text{Al(OH)}_3 + 2\text{H}^+\)
  
  - \(\text{Al(OH)}_3 + \text{H}_2\text{PO}_4^- \rightarrow \text{Al(OH)}_2\cdot\text{HPO}_4 + 2\text{H}_2\text{O}\)

- PAC products are “pre-hydrolyzed” and generate less acid byproduct

  - Alkalinity consumption inversely related to basicity
Advantages over Alum

- Demonstrated performance to reduce total P to ultra-low levels
- Has lower impact on pH and consumes less alkalinity than alum
- Higher aluminum concentration, less volume required
- Increased settling rates
- Increased dewatering capabilities
Advantages over Iron-based Products

- Non-staining
- Less corrosive – does not consume as much alkalinity
- Less impurities – not a by-product material
- Higher active ingredient concentration
- Iron can transition between Fe$^{+3}$ and Fe$^{+2}$
  - Fe$^{+2}$ not effective for P removal
PAC Case Studies
WI Case Study #1

- Treats ~1 MGD of wastewater
- Utilizes oxidation ditch for treatment
  - No primary clarifiers or filters
- Preparing for upcoming TP target of 0.075 mg/L
WI Case Study #1

- Optimized bio-P processes to reduce effluent TP to 0.3-0.5 mg/L

- Prepared by testing various chemical coagulants:
  - Alum
  - PAC

- Future testing may involve various independent polymers and filter trials
WI Case Study #1

Effluent Total Phosphorus (mg/L)

- Alum Added: 04/24
- PAC Added: 05/22

0.075 mg/L Target
Volume of PAC added: 120 GPD

<table>
<thead>
<tr>
<th>Month</th>
<th>Ave. Effluent Total P</th>
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<tbody>
<tr>
<td>March 2017</td>
<td>0.405 mg/L</td>
</tr>
<tr>
<td>April 2017</td>
<td>0.247 mg/L</td>
</tr>
<tr>
<td>May 2017</td>
<td>0.155 mg/L</td>
</tr>
<tr>
<td>June 2017</td>
<td>0.100 mg/L</td>
</tr>
<tr>
<td>July 2017</td>
<td>0.069 mg/L</td>
</tr>
<tr>
<td>August 2017</td>
<td>0.056 mg/L</td>
</tr>
</tbody>
</table>
• Treats ~2 MGD wastewater

• Uses combination of oxidation ditch, chemical addition, and anthracite filters for treatment
  - No primary clarifier

• Preparing for upcoming 0.075 mg/L Total P target
WI Case Study #2

- Does not have ability for enhanced bio-P
  - Low incoming BOD/VFA’s

- Previously tested rare earth coagulant
  - Stopped use due to increase in price

- Switched to PAC product in December 2016
  - Maintained average Total P of < 0.075mg/L using approx. 140 GPD
• Treats 8-10 MGD wastewater

• Uses traditional treatment
  - Primary Clarification
  - Extended aeration
  - Chemical P Removal
  - No filtration

• Future TMDL permits require discharge of < 18 lbs of P
  - Equates to ~0.18 mg/L effluent total P
WI Case Study #3

Effluent Total P (mg/L)

Date

Alum

FeCl₃

PAC

Enhanced PAC
WI Case Study #3

- **Alum:**
  - Average Volume: 215 GPD
  - Average Effluent Total P: 0.465 mg/L

- **FeCl₃:**
  - Average Volume: 230 GPD
  - Average Effluent Total P: 0.228 mg/L

- **PAC product**
  - Average Volume: 230 GPD
  - Average Effluent Total P: 0.259 mg/L

- **Enhanced PAC product**
  - Average Volume: 200 GPD
  - Average Effluent Total P: 0.121 mg/L
PAC versus Enhanced PAC
Questions?

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