Phosphorus Removal Treatment Alternatives
A Plainville, CT Case Study

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Presentation Outline

- **Case Study: Plainville, CT Phosphorus Removal**
  - Phosphorus Removal Overview
  - Biological Phosphorus Removal
  - Multi-Point Chemical Addition
  - Tertiary Solids Removal Processes
Plainville WPCF

- **Flows (MGD)**
  - Current avg: 2.0
  - Design avg: 2.6
  - Max Day: 6.0
  - Peak Hour: 7.5

- **’06-‘10 Upgrade**
  - New SBRs
  - New UV System
  - Sludge Tanks
  - Nitrogen Removal

- **No Provisions for Phosphorus Removal!**
New Phosphorus Limit

- **CT DEEP Phosphorus Strategy**
  - Published in 2011
  - 3.49 lbs/day Apr – Oct
    - 0.16 mg/l at plant design flow rate (2.6 mgd)
    - 0.11 mg/l at permitted flow rate (3.8 mgd)

- **Final NPDES Permit**
  - Issued June 20, 2015
  - Phosphorus Removal Deadline: July 10, 2019
  - DEEP suggested future limits may be lower
    - Design for 0.10 mg/l

- **2013 effluent phosphorus was 50 lbs/day!**
Phosphorus Removal Overview

Make it Solid
Remove the Solid
Phosphorus Removal

Biological

Physical/Chemical
Typical Approaches

■ For Moderate Level of P Removal (to 0.5 mg/l)
  – Enhanced Biological Phosphorus Removal (EBPR) and/or Chemical

■ For Lower Level of P Removal (to 0.2 mg/l)
  – Above with more chemical
  – Tertiary clarification or filtration (remove the solids)
  – Some facilities have demonstrated <0.2 mg/L with only EBPR and good clarification/filtration

■ For Lowest Levels of P Removal (<0.2 mg/l)
  – Advanced treatment/solids removal
  – Often with biological and/or chemical upstream of advanced treatment so that influent phosphorus <1.0 mg/l
  – Greater control of chemical process
What are Forms of Phosphorus?

- Ortho Phosphate
- Reactive Phosphorus
- Non Reactive Phosphorus
- Soluble Phosphorus
Phosphorus Comes In Many Different Forms

- Dissolved Organic
- Particulate Poly & Meta
- Dissolved Poly & Meta
- Particulate Organic
- Dissolved Ortho
- Particulate Ortho
Most NPDES Permits Will Limit Effluent Total Phosphorus
Dissolved Phosphorus Can Be 50% Or More Of Influent Total P

- Dissolved Phosphorus
- Particulate Phosphorus
Phosphorus Compounds Are Transformed During Wastewater Treatment

- Reactive Phosphorus (PO₄)
- Particulate Phosphorus
- Needs To Be Reacted
- Waste Sludge

Options for treatment:
- Biological Treatment
- Chemical or Biological Treatment
How is Phosphorus Removed by Biological Treatment?

- **Phosphorus is removed in typical activated sludge systems**
  - VSS is 1.5% - 2.5% phosphorus
  - Rule of thumb: 1 mg/L TP is removed for every 100 mg/L BOD

- **Enhanced Biological Phosphorus Removal (EBPR)**
  - Cultivate Phosphorus Accumulating Organisms (PAOs)
  - VSS is 6%+ phosphorus
  - Roughly 3x more phosphorus removed
**EBPR Basics**

- **Phosphorus Release**
  - No Oxygen
  - No Nitrate
  - Requires VFAs
  - Poly -> Ortho

- **Phosphorus Luxury Uptake**
  - Polyphosphate Accumulating Organisms (PAOs)
  - Requires Oxygen

- **Aerobic**

- **Anaerobic (1-2 hour HRT)**

- **Secondary Clarifiers**
  - RAS
  - Remove the solid

- **Make it solid**

- **WAS**
EBPR Challenges

- Competition between biological nitrogen removal and biological phosphorus removal optimization

- Biological process susceptible to upsets
  - Long recovery time
  - May need backup plan

- Re-release in anaerobic conditions
  - Sludge must be aerated to avoid returning phosphorus
May be possible, but…
- Limited SBR cycle time
- Competition with nitrogen removal
- Preventing phosphorus release in sludge holding tanks requires 24/7 blower operation

Conclusion:
- Plan on trying to optimize EBPR full-scale to reduce chemical costs
- Don’t depend on EBPR alone
Chemical Phosphorus Removal Basics

1. **Make it Solid**
   - Coagulation – reaction with metals to decrease solubility
   - Flocculation – make particles larger

2. **Remove the Solid**
   - Remove phosphorus-containing sludge from the system
Make it Solid: Coagulation
What Chemicals Are Used?

**Metal Salts**
- Ferric Chloride (Ferric)
- Aluminum Sulfate (Alum)
- Polyaluminum Chloride (PACl)
- Others (Lime, Ferrous salts, Sodium Aluminate, Ferric Sulfate, Aluminum Chlorohydrate, Polyaluminum Sulfate, RE300)
Make it Solid: Coagulation
Where Do We Add Chemicals?

- Multi-point addition reduces overall chemical use

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Multi-Point Chemical Addition for Phosphorus Removal

Primary Clarifiers → Biological Treatment → Secondary Clarifiers → Tertiary Treatment

- Coagulant Addition Point #1
- Coagulant Addition Point #2
- Coagulant Addition Point #3

RAS → WAS

Tighe&Bond
Coagulant Dose
- Under dosing means inadequate P removal
- Overdosing could lead to other effluent discharge issues and excess sludge produced
  » metals, pH, etc.

Dose is highly variable

Theoretically 1 part metal to 1 part P

Generally much greater than 1:1 for low levels

Jar testing can help
Make it Solid: Coagulation
How Do We Add Chemicals?

■ Rapid mixing required!
## Coagulant Chemicals Comparison

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>pH Impacts</th>
<th>Relative Cost</th>
<th>Metals Impacts</th>
<th>Other Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric</td>
<td>- - -</td>
<td>$</td>
<td>Zinc and Copper</td>
<td>Stains UV Sleeves</td>
</tr>
<tr>
<td>Alum</td>
<td>- -</td>
<td>$</td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>PACI</td>
<td>-</td>
<td>$$</td>
<td>Aluminum</td>
<td>Proprietary</td>
</tr>
<tr>
<td>Sodium Aluminate</td>
<td>+</td>
<td>$$</td>
<td>Aluminum</td>
<td>Poor cold weather performance</td>
</tr>
<tr>
<td>RE300</td>
<td>?</td>
<td>$$$</td>
<td>?</td>
<td>Limited testing in CT</td>
</tr>
</tbody>
</table>

- Consider flexibility to use any coagulant for future metals limits!
EBPR alone isn’t suitable
– Therefore, chemical phosphorus removal is required

Effluent TP limit is well below 0.5 mg/l
– Therefore, advanced/tertiary solids removal is required

Tertiary solids removal systems generally perform best at influent TP levels <1.0 mg/l
– Therefore, primary and secondary solids removal should be optimized for SBR effluent TP <1.0 mg/l

Next question: which coagulant is best for Plainville?
Which Coagulant Is Best for Plainville?

- Jar test results didn’t show a clear winner
  - Tighe & Bond testing suggested PACl
  - Vendor pre-selection testing struggled with PACl
  - Vendor validation testing struggled with Alum
  - Different chemicals may be more effective at different points

- Aluminum limit not in current permit… but may be in the next one!

- Ferric is considered a last resort
  - Safety concerns; UV corrosion

- Conclusion:
  - Two separate systems, each compatible w/ ferric, alum, or PACl
Remove the Solid

- Coagulation with Primary and Secondary Solids Removal can achieve approximately 0.5 mg/l TP

- Lower TP levels require advanced (tertiary) treatment to remove additional solids
  - Deep Bed Sand Media Filtration
  - Ballasted Flocculation
  - Cloth Media Filtration
**Cloth Media Filters**

- **Typically Effective to 0.2 - 0.1 mg/L**

- **Advantages**
  - Consumes energy only during backwash
  - No ballast to lose and replace
  - Simple control system
  - Little operator attention

- **Disadvantages**
  - Large coagulation/flocculation tanks
  - Recycle flow rate fluctuates
  - Solids-limited
Deep Bed Sand Media Filters

- **Typically Effective to 0.1 - 0.05 mg/L**

- **Advantages**
  - No separate coagulation/flocculation tanks required
  - No polymer system required

- **Disadvantages**
  - Continuous replacement of lost sand media
  - High recycle flow rates (up to 4% of forward flow)
  - Many filters, diurnal on/off
  - Significant O&M effort
  - Continuous backwash -> higher energy cost

Photo Credits: Blue Water Technologies
Ballasted Flocculation

- **Typically Effective to 0.1 - 0.05 mg/L**

- **Advantages**
  - Ballast reduces size of coagulation/flocculation tanks required
  - Better than filtration technologies at peak flows and solids

- **Disadvantages**
  - Continuous replacement of lost ballast
  - Additional sludge generation from lost ballast
  - Complex operation
  - Recycle flow rate fixed based on peak hour design (3%)
  - Significant O&M effort

Photo Credits: Evoqua Water Technologies
# Phosphorus Removal Summary

<table>
<thead>
<tr>
<th>Technology</th>
<th>Typical Effluent Limit</th>
</tr>
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<tbody>
<tr>
<td>Enhanced Biological Phosphorus Removal</td>
<td>1.0 to 0.5 mg/L</td>
</tr>
<tr>
<td>Chemical: Primary &amp; Secondary Clarifiers</td>
<td>1.0 to 0.5 mg/L</td>
</tr>
<tr>
<td>Chemical: Granular Media Filters</td>
<td>0.2 mg/L</td>
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- **Selected Cloth Media Filters based on life cycle cost and low O&M**
Phosphorus Removal Project

- **Pre-selected Kruger discfilters**
  - Recently completed validation testing

- **Design is currently 60% complete**
  - Construction: 2018 - 2020

- **Total project cost: $15,000,000**
  - Including flow EQ tank & pumps, filter building, solids handling improvements and UV system resiliency improvements