WRRF Nutrient Recovery and Sustainable Biosolids Management
Treasure Coast Regional Biosolids Symposium, Stuart, Florida

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Why Do We Need Nutrient Recovery Capability in WRRF’s?

- Complements nutrient removal
- Represents resource recovery
- Highly marketable end-product
- Contributes to sustainable nutrient management
- Provides factor of safety for Bio-P
- Minimizes impact of sidestream loads
- Reduces chemical consumption (sidestream treatment)
- Reduction in sludge quantity and hauling costs
- Minimizes nuisance struvite formation
- Reduces P content of biosolids
- Improves biosolids dewaterability
- Higher sludge cake %TS
- Reduces polymer demand
What is Nutrient Recovery?

- Accumulation step to increase N content > 1000 mg N/L and P content > 100 mg P/L
- Release step to generate low flow and high nutrient stream
- Recovery step produces high nutrient content product
Potential Locations for Nutrient Recovery at Water Resource Recovery Facilities

- Residuals Resource Recovery
- Primary Clarifier
- Final Clarifier
- Anaerobic Digester
- Primary Sludge
- Bio-P Process
- P recovery
- Centrate/Filtrate
- WAS
- Incineration
- Ash
- N and P recovery
- RAS
- P recovery
The WERF Nutrient Recovery Project

Phase 1
State of Science Review of extractive nutrient recovery
I. State of Science Report
II. Market Analysis

Phase 2
Provide guidance on the implementation of recovery technologies at WWTPs
I. Tool for evaluating resource recovery (TERRY)
II. Case Studies

Phase 3
Experimentally evaluate recovery technologies
I. Evaluate high priority embryonic P recovery technologies
WERF Project Team

- Project Team led by:
  - Hazen and Sawyer
  - CH2MILL (now Jacobs)

- Utilities: 20

- National & international experts
  - Universities & research organizations
    - USA
    - Australia
    - Europe
    - Japan

- Technology providers: 6
Phosphorous flows and concentrations in a WRRF

Inlet: 100% ~ 1.80 g P/(E*d)

Primary Sludge: 10% ~ 0.18 g P/(E*d)

Outlet: 10% ~ 0.18 g P/(E*d)

WAS: 80% ~ 1.45 g P/(E*d)

WAS is the main carrier for phosphate.
Waste activated sludge from a BNR facility contains approximately:

- 12% nitrogen
- 5% phosphorus

Can be recovered as struvite

It has Taken us 6,000 years to realize that our poop is priceless!
Benefits of Nutrient Recovery

- Lowers energy use and greenhouse gas emissions associated with fertilizer production.
- Minimizes struvite scaling.
- Stabilizes Bio-P performance by reducing sidestream loads.
- Lowers biosolids P content – higher land application rates.
- Recovers N &P as struvite, a slow-release fertilizer.
- Enhances biosolids dewaterability.
- Creates a modest revenue stream.
- Aligns with the ‘plant of the future’ vision.
Why is Phosphorous Recovery from WRRF’s so Important?

Phosphate:
- Limited resource (30 - 300 yrs)
- Direct correlation to phosphate production and world population

World Phosphate Rock Reserves

World rock phosphate production vs world population

- Morocco & Western Sahara 53%
- China 6%
- United States 5%
- Jordan 5%
- South Africa 5%
- Brazil 4%
- Russia 3%
- Israel 3%
- Tunisia 3%
- Egypt 3%
- Syria 3%
- Australia 3%
- Senegal 3%
- Topo 2%
- Canada 2%
- Other countries
What is Struvite?

- Struvite is Magnesium Ammonium Phosphate (MgNH₄PO₄)
  - Kidney stones
- Historical perspective
  - First observed in sewer systems in 1845 in Hamburg, Germany
  - Named after geologist Gottfried von Struve
  - Value as a fertilizer dates back to 1857
- Forms readily when:
  - Molecular ratio of Mg:N:P is 1:1:1
  - pH around 9.0.
- Often an O&M nightmare at plants with anaerobic digesters:
  - Anaerobic digestion releases the necessary ‘raw materials’
  - Turbulence drives out CO₂ resulting in pH rise & struvite scaling
Recovery from Wastewater Requires a Three-Step Framework

- **Accumulation**
  - Bio-P
  - Algae
  - Purple non-sulfur bacteria
  - Adsorption/Ion exchange
  - Chemical precipitation
  - NF/RO

- **Release**
  - Anaerobic digestion
  - Aerobic digestion
  - Thermolysis
  - WAS release
  - Sonication
  - Microwave
  - Chemical extraction

- **Extraction**
  - Chemical crystallization
  - Electrodialysis
  - Gas permeable membrane and absorption
  - Gas stripping
  - Solvent extraction
# Proven P Recovery Technologies

<table>
<thead>
<tr>
<th>Feature</th>
<th>Ostara Pearl®</th>
<th>Multiform Harvest</th>
<th>NuReSys</th>
<th>Phospaq</th>
<th>Crystalactor</th>
<th>Airprex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of reactor</td>
<td>Fluidized Bed Reactor (FBR)</td>
<td>FBR</td>
<td>Completely Stirred Tank Reactor (CSTR)</td>
<td>CSTR</td>
<td>FBR</td>
<td>CSTR</td>
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<tr>
<td>Point of Recovery</td>
<td>Centrate/Filtrate</td>
<td>Centrate/Filtrate</td>
<td>Centrate/Filtrate; digested sludge</td>
<td>Centrate/Filtrate</td>
<td>Centrate/Filtrate</td>
<td>Digested sludge</td>
</tr>
<tr>
<td>Recovery efficiency</td>
<td>80-90% P 10-40% NH3-N</td>
<td>80-90% P 10-40% NH3-N</td>
<td>&gt;85% P 5-20% N</td>
<td>80% P 10-40% NH3-N</td>
<td>85-95% P for struvite 10-40% NH3-N &gt; 90% P for calcium phosphate</td>
<td>80-90% P 10-40% NH3-N</td>
</tr>
<tr>
<td>Full-scale installations</td>
<td>10</td>
<td>2</td>
<td>7</td>
<td>3</td>
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<td>3</td>
</tr>
</tbody>
</table>
Fluidized Bed Reactor (Ostara, Multiform Harvest, Crystalactor)

- Magnesium
- Caustic
- Centrate/Filtrate: High NH3-N and PO4-P
- Dewatering
- FBR
- Effluent: 80-90% P removal, 15-30% N removal
- Dryer
- Struvite: MgNH4PO4•6 H2O
- Sand 1 (Crystalactor)
Waste Activated Sludge Stripping to Recover Internal Phosphate (WASSTRIP®)
AirPrex

Struvite Recovery from Digested Sludge
WERF Deliverables

• Final WERF report including TERRY released August 2015
• User manual and tutorial
• Who do we envision using TERRY?
  – Utility managers, research and development personnel
  – Consultants
  – Regulators
Tool for Evaluating Resource Recovery (TERRY)

- User friendly Excel tool
  - High level evaluation of site-specific feasibility of implementing extractive nutrient recovery
  - Beta-tested by several major US and Canadian utilities

- Allows
  - Net present worth comparison of struvite recovery & chemical sidestream P treatment
  - Business case evaluation taking into account 13 criteria such as:
    - Cost
    - Technology performance
    - Environmental/ socials impacts
    - Technology maturity
    - Plant-wide impacts
  - Payback analysis
  - Technology factsheets available within the tool so that technology options can be compared
Beneficial Use of Biosolids
Technologies producing higher quality products and recovering more energy

- Biosolids
- Compost
- Soil Amendment
- Fertilizer
- Char
- Ash

- Thickening
- Anaerobic Digestion
- Dewatering
- Drying
- Gasification
- Incineration with Energy Recovery
Beneficial Use of Biogas
Technologies with greater efficiencies and lower emissions

Biogas

Fuel
Biomethane
Heat
Power

Engines, Turbines, Fuel Cells
Disruptive Approaches are Needed to go from Treatment to Product Recovery

- Biorefinery
- Increasing Level of Disruption
- Wastewater Treatment

1. Basic Sanitation
   - cBOD, Solids & pathogens

2. Environmental Protection
   - TN & TP
   - Nitrification

3. Sustainability & Human Survival
   - Nutrient, Energy, Water
   - Chemicals
   - Biofuels
   - Bioplastics
   - Metals
   - ?
What does the WRRF of the future look like?

Key attributes of a WRRF of the future:

• Operate as a production center/biorefinery
  ➢ Water factory
  ➢ Energy factory
  ➢ Resource (nutrient and organics) factory
    ➢ Fertilizer manufacturing facility for example

• Carbon neutral; energy self-sufficient
• Centralized and decentralized systems
• Highly automated
• Increasingly resilient
• Doing more with less (intensification)
• In a highly regulated environment
Some summary thoughts…

• Leadership must articulate a vision for the future – be bold!
• Consider non-traditional approaches to bridge gaps – dare to disrupt!
• Staff must be involved, empowered, motivated, and accountable – seek buy in!
• Know where are you starting from – develop a baseline!
• Implement changes incrementally, reassess frequently, and have a contingent plan – no regrets!
• Involve the community you serve – communicate!
• Learn from others; share results – collaborate!
“You’ve got to be very careful if you don’t know where you are going, because you might get there.”

“In theory there’s no difference between theory and practice. In practice there is.”

Yogi Berra

Courtesy: Glen Daigger
Thank You!
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