Building Upon Practice and Knowledge of Early Adopters of Sidestream P Recovery

Bryan Coday, Ph.D., P.E.
Eutrophication is regarded as the most important environmental problem caused by phosphorus loss

• P is typically the limiting nutrient responsible for eutrophication

• Significant eutrophication occurred in the Great Lakes circa 1950

• Still a prevalent issue in many lakes and estuaries around the world

Lake Mead, Nevada
Eutrophication-associated dead zone distribution matches the global human footprint

Eutrophication-associated dead zone distribution matches the global human footprint


Red Tide – Florida Coastline
EPA Nutrient criteria developed by State today...

Level 5: Complete set of N and P criteria for all watertypes
Level 4: 2 or more watertypes with N and/or P criteria
Level 3: 1 watertype with N and/or P criteria
Level 2: Some waters with N and/or P criteria
Level 1: No N and/or P criteria

Legend:
- District of Columbia
- American Samoa
- Commonwealth of Northern Mariana Islands
- Guam
- Puerto Rico
- US Virgin Islands

US EPA Nutrient Policy Data - 2018
Phosphorus removal still has a ways to go...

CWNS, USEPA 2012
Human activities have intensified the natural nutrient cycle, resulting in significant environmental problems.

- Green zones represent safe operating space.
- Red wedges represent an estimate of current position for each variable.
- The boundary for three systems have already been exceeded.

Worldwide phosphorus reserves and production concentrated in few countries

- Several hundred years of phosphate reserves at current production rates
- Per USGS, China and U.S. will deplete recoverable reserves within 40 years
Is peak phosphorus really on the horizon? Can we afford to do nothing?

P Recovery in WRRF Facilities
Aggregated phosphorus mass flows by end use in the U.S.

Rauch-Williams, et al., 2018, *Preparation of Baseline Data to Establish the Current Amount of Resource Recovery*
Phosphorus recovery by utility size

Rauch-Williams, et al., 2018, *Preparation of Baseline Data to Establish the Current Amount of Resource Recovery*
Biological phosphorus removal

**Anaerobic**
- VFA
- Glycogen
- Ac-COA
- EMP
- NADH
- Energy
- PHB
- Poly-P
- PO4
- Released P
- Influent P

**Aerobic**
- CO2 + H2O
- Glycogen
- PHB
- Poly-P
- Cell + Poly-P
- PO4
- Released P
- Influent P
Simplified P mass balance without BioP

- **Primary Treatment**
- **Secondary Treatment**
- **Anaerobic Digestion**
- **Dewatering**
- **Biosolids**
- **Effluent**

- **~10 Percent**
- **~30 Percent**
- **~60 Percent**
Simplified P mass balance with BioP

- Primary Treatment
- Secondary Treatment
- Anaerobic Digestion
- Dewatering
- Biosolids
- Effluent

~10 Percent

~80 Percent

<10 Percent

~20-40 Percent of Secondary Treatment P Load
Key rationale for implementing sidestream P sequestration or recovery

- Mainstream C:P Ratio
- Carbon Demand
- Less P recycle reduces struvite potential
- Revenue Stream Potential
- Improved Dewaterability Potential
Phosphorus Mass Balance with BioP and P Recovery

Primary Treatment

Secondary Treatment

Effluent

Up to 90% Recovery
Struvite

Up to 90% Conversion of Soluble P
P Sequestering

~10 Percent
Biosolids

~80 Percent
Dewatering

Anaerobic Digestion

<10 Percent
The Early Adopters of P Recovery
Early adopters of P recovery have generally targeted struvite.
Where can struvite be sequestered/recovered from solids handling?

Areas for Recovery:
1. Digestate
2. Centrate

Performance:
- Up to 90% conversion of available OP
Simplified overview of how phosphorus removal/recovery works

1. Aeration to strip CO$_2$ or chemical addition for pH adjustment
2. Addition of Magnesium
3. MAP – Crystallization and settling
4. MAP – Separation and washing

Adapted from CNP
Major phosphorus recovery vendors currently in the market

- AirPrex (CNP/Centrisys)
- Ostara
- Nuresys (Schwing Bioset)
- Multiform Harvest
- KREPO
- Seaborne
- Kemicond
- BioCon
- SEPHOS

Under development in Europe
We surveyed and visited many of these facilities
Centrysis

- AirPrex™ technology developed in Germany in 2010 in utility/university collaboration
- Patent purchased then sold to CNP -> Centrysis
- Several installations in Germany with some design modifications over time
  - 1-stage reactor
  - 2-stage reactor
  - CalPrex™
- Strong interest in pilot testing in the US, now two facilities under construction
  - MWRD and Ft. Collins currently in design
AirPrex™ (One reactor configuration)
Installation example: Berlin Wassmannsdorf
AirPrex™ (Two reactor configuration)
Installation example: Amsterdam, NL
AirPrex™ (Two reactor configuration)
Installation example: Amsterdam, NL

~ 44 mgd Design Average Dry Weather Flow
Marketed benefits and feedback of the AirPrex™ system

• Reduced soluble P recycle load (up to 90%)
• Reduced polymer consumption (~20 percent)
• Improved sludge cake dryness
• Reduced biosolids hauling costs
• Reduced nuisance struvite formation
Multiform Harvest

• Technology developed in US out of Ph.D. work by Keith Bowers

• Original installations in farming/manure businesses,
  – Domestic wastewater started about 6 years ago

• Struvite product is smaller and less homogenous than Ostara Pearl product

• Technology designed for utilities who want to remove phosphorus and retain more control over the end product

• Technology can be implemented with and without a P release tank
Multiform Harvest without Multi-WAS
Multiform Harvest with Multi-WAS
Multiform Harvest Purchased by Ostara


Announced today, tech acquisition expands reach of nutrient recovery to new markets.

Ostara Nutrient Recovery Technologies Inc. (“Ostara”) and Multiform Harvest Inc. (“Multiform”) announced recently, the closing (“Closing”) of the acquisition (the “Acquisition”) by Ostara, of substantially all of the assets of Multiform pursuant to an Asset Purchase Agreement (the “Agreement”) entered into by Ostara, Multiform and certain key shareholders of Multiform on August 24, 2018. Pursuant to the Agreement, Ostara paid a portion of the purchase price at Closing and will deliver the remainder in two equal post-Closing payments by mid-2019. Closing of the Acquisition occurred on December 21, 2018.
Marketed benefits and feedback of the Multiform Harvest system

- Lowest capital and operating costs
- Easiest operation
- Smallest overall footprint
- Reasonably flexible design and operation
- 80-90% P recovery from centrate/filtrate
- Less refined product – resale facilitated by MFH
Ostara

- Developed in Canada, then spread into US and Europe
- Most number of installations in US to date
- System designed for struvite production and sale
- Struvite sold to company who will market
- Ostara stays involved in operation and advises regular on adjustments (weekly calls, electronic process data review)
Ostara PEARL® in the US

Rock Creek WWTF
~ 35 mgd treatment capacity

HRSD Nansemond WWTP
~ 30 mgd treatment capacity
Marketed benefits and feedback of the Ostara system

• 80-90% P recovery from centrate/filtrate
• Highly refined product – resale facilitated by Ostara
  – CrystalGreen
• Reduced nuisance struvite formation
• Typically higher upfront capital cost
• Long-term operational assistance and process input from Ostara
• Relatively higher degree of operational oversight
Schwing Bioset - NuReSys

- Belgian Company founded in 2011
- Several installation in Europe
- NuReSys technology now marketed in US by Schwing Bioset
- Just recently enter the US market, no full-scale installation
Schwing Bioset NuResys – centrate configuration
Schwing Bioset NuResys – digestate configuration

DAFT → Anaerobic Digesters → Sludge Storage (Optional) → Stripper Reactor → BIO-STRU Crystallizer and Settler → Cyclone (Optional) → Centrifuge Feed Storage → Centrifuges → Centrate EQ → To TFPS

- Supernatant to Mainstream
- MgCl₂
- Blowers
- Struvite bagging or incorporation into biosolids
Schwing Bioset NuResys – hybrid configuration

[Diagram showing the processes involved in the hybrid configuration.]
Schwing Bioset NuResys at Aquafin RWZI Leuven, BE

- Hydrocyclone
- Digester
- Struvite Collection Bin
- Grit Washer
- Settler
- Crystallizer
- MgCl storage
- Stripper
- Blower
Marketed benefits and feedback of the NuReSys system

- Reduced soluble P recycle load (up to 90%)
- Up to 45% struvite recovery
- Fertilizer product marketed as BioStru
- Reduced polymer consumption
- Improved sludge cake dryness
- Reduced biosolids hauling costs
- Reduced nuisance struvite formation
## Simplified technology comparison

<table>
<thead>
<tr>
<th></th>
<th>AirPrex</th>
<th>Multiform H.</th>
<th>Ostara</th>
<th>NuReSys</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reactor Type</strong></td>
<td>CSTR with Diffused Air</td>
<td>Upflow Fluidized Bed</td>
<td>Upflow Fluidized Bed</td>
<td>CSTR</td>
</tr>
<tr>
<td><strong>Technology Design</strong></td>
<td>Mid sized tank</td>
<td>Small tank</td>
<td>Large tank w/ recycle</td>
<td>Two tanks</td>
</tr>
<tr>
<td><strong>Source of P recovery</strong></td>
<td>Digestate</td>
<td>Centrate</td>
<td>Centrate</td>
<td>Centrate, Digestate, Hybrid</td>
</tr>
<tr>
<td><strong>pH adjustments</strong></td>
<td>Aeration</td>
<td>Chemicals</td>
<td>Chemicals</td>
<td>Aeration</td>
</tr>
<tr>
<td><strong>Chemical Type</strong></td>
<td>MgCl₂ or Mg(OH)₂</td>
<td>NaOH and MgCl₂</td>
<td>MgCl₂ or Mg(OH)₂</td>
<td>MgCl₂ or Mg(OH)₂</td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Labor Oversight</strong></td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Product Name</strong></td>
<td>Non-proprietary</td>
<td>Non-proprietary</td>
<td>Crystal Green</td>
<td>Bio-Stru</td>
</tr>
<tr>
<td><strong>Product Marketing</strong></td>
<td>Flexible</td>
<td>Flexible</td>
<td>By vendor</td>
<td>Flexible</td>
</tr>
</tbody>
</table>
## Lessons learned from others’ and past pitfalls

<table>
<thead>
<tr>
<th>Past Issue</th>
<th>Design Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Struvite precipitation in influent and effluent pipe</td>
<td>Site location and hydraulics</td>
</tr>
<tr>
<td></td>
<td>Feed and effluent pipe layout and material selection</td>
</tr>
<tr>
<td>Plugging of struvite extraction valve</td>
<td>Valves design, isolation valves, and flush system</td>
</tr>
<tr>
<td>Corrosion of carbon steel reactor</td>
<td>Consider SS reactor material and coating</td>
</tr>
<tr>
<td>Overaeration limits crystal formation</td>
<td>Adequate blower sizing to avoid overmixing</td>
</tr>
<tr>
<td>Localized chemical precipitation</td>
<td>Consider multiple MgCl$_2$ injection ports on reactor</td>
</tr>
<tr>
<td>Process failure because of foam formation, high TSS or polymer in influent</td>
<td>Bypass design, foam suppressant injection port, decant option, redundancy contingencies</td>
</tr>
<tr>
<td>Equipment does not match facility standards</td>
<td>Standardize components and warranty requirements</td>
</tr>
<tr>
<td>Limited options to accommodate technology development</td>
<td>Plan in space and flexibility for future process expansion</td>
</tr>
</tbody>
</table>
Questions and Discussion