West Boise WWTF
Use of Struvite Crystallization Technology as Part of the Phosphorus Removal Plan

- Dan Barbeau, P.E., Pharmer Engineering
- Bob Kresge, P.E., City of Boise Public Works
- Keith Bowers, PhD, Multiform Harvest Inc.
Snake River / Hells Canyon TMDL

• >220 River Miles
• Extremely complex and highly modified
• Phase approach (50 to 70 years implementation)
• 8 Pollutants (bacteria, nutrients, mercury, pesticides, sediment, temperature, TDG, pH)
• Approved for 4 Pollutants (nutrients, pesticides, sediment, TDG)
• Nutrient Target 0.07 mg/L for five tributaries (Boise, Payette, Weiser, Owyhee, Malhuer)

Per Robbin Finch
City of Boise
Lower Boise WWTF Target

- Total phosphorus at mouth, 0.07 mg/L
- IDEQ 2008 Point Source Targets at 0.200 mg/L TP for May through September
- EPA prefers point source allocations at 0.07 mg/L TP, monthly basis

Per Robbin Finch
City of Boise
City of Boise WWTFs

- **Lander Street WWTF.** Activated sludge and Class B digestion. Digested sludge pumped to West Boise
- **West Boise WWTF.** Activated sludge in two plants, Class B digestion, and dewatering of both plant’s biosolids
- **Twenty Mile South Farm.** City owned land application site for WWTF biosolids. Soil phosphorus load is an future challenge.
City of Boise

WWTF Phosphorus Removal Work

Partial List

- Mid 1990s Facility Planning
- Studies at Lander Street WWTF and West Boise WWTF around 2000-2001
- Other work 2002 and
- Pilot work in 2003
- West Boise hands on work 2006 and 2008
- West Boise Phosphorus, 2007 to present
  (Target was 1.0 mg/L Total Phosphorus)
City of Boise
WWTF Phosphorus Removal Project

Objectives

Find solutions for the following potential permit limits:

• 1.0 mg/L Total P
• 0.2 mg/L Total P
• 0.07 mg/L Total P
Phosphorus Removal at Filtrate

FILTRATE TREATMENT HERE
Choices for Filtrate/Sidestream Treatment for Phosphorus for West Boise WWTF Project

- Metal Salts, Aluminum or Iron
- Intentional Struvite Crystallization
What is Struvite

- Magnesium Ammonium Phosphate Hexahydrate
  \((\text{MgNH}_4\text{PO}_4\cdot6\text{H}_2\text{O})\)

- Sparingly soluble crystalline compound

- Good slow release fertilizer
Phosphorus Removal at Filtrate

FILTRATE TREATMENT HERE
West Boise WWTF Filtrate Treatment Evaluation 2002

Considered
- Evaluated various approaches to high strength filtrate treatment
- Metal Salts (Ferric, Alum, Sodium Aluminate)
- Intentional struvite precipitation

Findings
- Ferric was less expensive at the time
- Struvite appeared competitive, within 10% of chemical only option
Integrated Sidestream Alt. BK2f

(Presented to group January 2008)

West Boise WWTF – TP Removal to 1.0 mg/L

PFD BY CH2MILL
**Phosphorus Release Tank**

- WAS + High VFA stream, anaerobic release (contains high ortho-P and some magnesium)
- Remove phosphorus before digestion

**Digester Filtrate**

- Contains high ammonia

Combine two streams at struvite reactor
2008 Struvite Pilot

- Reactor and Pilot Work by Dr. Keith Bowers
  Multiform Harvest Inc
- Upflow fluidized bed reactor
- ~7 Minute HRT
- Dose influent and reagents at bottom
- Harvest from bottom
Ortho-Phosphate in Testing Periods

Period 1: Existing Belt Press Filtrate, Approx 65 mg/L Ortho-P, Small pH boost ~0.5 units,

Period 2: Simulated higher concentration with 150 mg/L Ortho-P augmented with phosphoric acid

Period 3: Simulated higher concentration with >1,000 mg/L Ortho-P augmented with phosphoric acid
High Concentration System (1,200 mg/L P)

Overdose of reagents can lead to nucleation / dusting

System Requires Thoughtful Operation
Struvite Process Effluent

- Reactor effluent is cleaner
- Lower ammonia and phosphorus
Relative Pilot Results

West Boise WWTF 2008 Pilot
Reduction (%) in Total P vs. Saturation Index

Total P Reduction %

Saturation Index

Period 1
Period 2
Period 3
Struvite Process Product

- Product material is a 5-28-0 + 10% Mg fertilizer
- Mesh varies
- Sometimes dusty
- Market minimally developed to date

Mesh varies
Implementation
Implementation

New struvite facility adjacent to existing filtrate basins
Section – Six Reactor System
What is Struvite Worth

- MAP (10:52), commodity level ~ $400 (in 2008 3+x)
- Struvite (5:28), commodity level (theoretical) ~ $200/DT
- As a slow release Mg/combined, retail ~ $800/DT - ~ $1,200/DT
- MagAMP was selling for, retail ~ $3,500/DT
- Best guess, raw product ~ $300/DT to ~ $600/DT
  (As a niche market fertilizer)
- Guess as unprocessed commodity ~ <$100/DT

Higher value of struvite requires there be a developed niche market
Struvite Economics

In Conventional Filtrate Treatment

- Capital Cost Opinion $3.3 million (w/ >25% Contingency)
- Annual Related Costs
  - Power
  - Heat
  - Labor
  - Magnesium Chloride
  - Caustic
  - Hauling
  - Operational Cost Contingency at ~50%
  - (Product Revenue)
## Struvite Economics

### In Conventional Filtrate Treatment

**West Boise WWTF**

**Phosphorus Removal Evaluation**

**Traditional Filtrate Treatment**

**Struvite Payback Analysis - Range of Raw Product Values**

<table>
<thead>
<tr>
<th>Raw Struvite Product Value ($/DT)</th>
<th>Total Annual Cost ($/Yr)</th>
<th>Total Net Present Value A,B,C ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0</td>
<td>$576,777</td>
<td>$9,910,000</td>
</tr>
<tr>
<td>$100</td>
<td>$438,137</td>
<td>$8,320,000</td>
</tr>
<tr>
<td>$200</td>
<td>$299,497</td>
<td>$6,730,000</td>
</tr>
<tr>
<td>$300</td>
<td>$160,858</td>
<td>$5,140,000</td>
</tr>
<tr>
<td>$400</td>
<td>$22,218</td>
<td>$3,550,000</td>
</tr>
<tr>
<td>$600</td>
<td>($255,061)</td>
<td>$370,000</td>
</tr>
<tr>
<td>$800</td>
<td>($532,341)</td>
<td>($2,820,000)</td>
</tr>
<tr>
<td>$1,000</td>
<td>($809,620)</td>
<td>($6,000,000)</td>
</tr>
</tbody>
</table>

A. 0.12 MGD struvite facility at 1,200 lbs/d P feed  
B. Capital cost opinion at $3.3 million for the struvite facility  
C. Payback calc includes only struvite facility capital and operating costs  
D. 20 year return period with 6% discount rate
Metal Salt Economics

In Conventional Filtrate Treatment

- 80% Removal of filtrate phosphate = 960 lb/d
- At 1:1 (Fe:P) dose, need 12,500 lb/d ferric solution (40% by weight)
- Costs:
  - At $0.26 / lb solution, $3,250 / day
  - Sludge, labor, maint costs; ~ half of chemical $1,600 / day
    (does not include capital and associated facility derating)
  - Total ~$4,875 / day
- 6 months per year: $890,000 / year
  - (20 yr PW= ~ $10 million)
- 12 months per year: $1,780,000 / year
  - (20 yr PW= ~ $20 million)
In Conventional Filtrate Treatment

Conclusions

- Metal Salt Filtrate Treatment vs Struvite System on Filtrate
  - Zero product value of struvite = break even costs for 6-month permit limit
  - Zero product value on struvite for 12-month permit, struvite present worth is half of the metal salt
  - At $600/DT raw product value (for this situation), facility pays for itself (mining break even)
Struvite Economics

Integrated Sidestream BK2f

- Tradeoff economics less straightforward
- For 1.0 mg/L TP effluent target, process model suggests success without sidestream or filtrate treatment
- More cost effective with lower limits, avoided chemical costs

<table>
<thead>
<tr>
<th>Discharge Goal / Alternative</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TP 1.0</strong></td>
<td></td>
</tr>
<tr>
<td>Bio-P Conversion w/ Fermentor</td>
<td>$8 million</td>
</tr>
<tr>
<td>Bio-P, Fermentor, Bk2f</td>
<td>$19 million</td>
</tr>
<tr>
<td><strong>TP 0.2</strong></td>
<td></td>
</tr>
<tr>
<td>Bio-P, Fermentor, Filters</td>
<td>$34 million</td>
</tr>
<tr>
<td>Bio-P, Fermentor, Bk2f, Filters</td>
<td>$44 million</td>
</tr>
<tr>
<td><strong>TP 0.07</strong></td>
<td></td>
</tr>
<tr>
<td>Bio-P, Fermentor, Chem Clarifiers, Filters,</td>
<td>$43 million</td>
</tr>
<tr>
<td>Bio-P, Fermentor, Bk2f, Filters</td>
<td>$45 million</td>
</tr>
</tbody>
</table>
Integrated Sidestream BK2f

Conclusions

- Economics show BK2f more expensive for 1.0 mg/L total phosphorus, requires more product revenue, but it is close
- Non-economic factors are significant
  - Over two times phosphorus removed, that does not go to farm
  - Digester unintentional struvite formation avoided
Phosphorus: The Enemy

- Too much P and N can cause algae blooms (algae is 16N:1P)
- In 12 of 16 EPA Regions, 90% of rivers contain excess nutrients (most is from non-point)
- Over 1000 water bodies in the Pacific Northwest are nutrient limited
- For the West Boise WWTF, estimated effort is between $34 and $45 million, depending on where the final limit is.
Phosphorus: Uses

- Food Production / Fertilizers
- Synthetic detergents
- Industrial (cleaning)
- Corrosion control

World Production of Phosphorus Depends on Phosphate Rock Reserves
World phosphate reserves will be consumed in 50 to 100 years.
West Boise WWTF
Use of Struvite Crystallization Technology as Part of the Phosphorus Removal Plan