WELCOME
TO THE JUNE EDITION
OF THE 2012
M&R SEMINAR SERIES
BEFORE WE BEGIN

• SILENCE CELL PHONES & PAGERS

• QUESTION AND ANSWER SESSION WILL FOLLOW PRESENTATION

• SEMINAR SLIDES WILL BE POSTED ON MWRD WEBSITE AT (www. MWRD.org)

• Home Page ⇒ (Public Interest) ⇒ more public interest
  ⇒ M&R Seminar Series ⇒ 2012 Seminar Series
Charles B. Bott, Ph.D. P.E., BCEE

Career
Research and Development Manager at HRSD
Adjunct Professor in the Dept of Civil and Env Eng at Virginia Tech and Old Dominion University
Associate Professor in the Dept of Civil and Env Eng at the Virginia Military Institute (VMI)
Consulting Engineer with Parson Engineering Science

Professional
Registered Professional Engineer: Virginia
Board Certified Environmental Engineer (BCEE)
Board of Trustees, Water Environment Federation
Science and Technical Advisory Committee to the Chesapeake Bay Program Executive Council

Education
Ph.D in Civil and Env Eng, Virginia Tech;
MS in Env Eng, Johns Hopkins University
BS in Civil Eng, Virginia Military Institute,

Awards
Winner of the WEF Harrison Prescott Eddy Medal
Winner of the Water Environment Federation (WEF) Outstanding Young Professional Award

HRSD
Struvite Recovery at the HRSD Nansemond Treatment Plant

Charles B. Bott, PhD, P.E., BCEE
Hampton Roads Sanitation District
Hampton Roads Sanitation District

- Created in 1940
- Serves 1.6 million people
- Includes 17 jurisdictions – 3,100 square miles
- 9 plants, 4 small plants
- Capacity of 249 MGD
HRSD’s Bubble Permit - 2011

- James River
  - 6,000,000 lbs/yr TN
  - 573,247 lbs/yr TP
- York River
  - 288,315 lbs/yr TN
  - 33,660 lbs/yr TP
- Rappahannock River (one plant)
  - 1,218 lbs TN
  - 91 lbs/yr TP
Chesapeake Bay TMDL & VA WIP

• Nitrogen – James River
  – 2011 – 6.0 million pounds/year
    ▪ Major upgrades ongoing at Nansemond, James River, Williamsburg, Army Base
    ▪ Upgrade at Boat Harbor (minimal N removal)
  – 2017 – 4.4 million pounds/year
    ▪ VIP - upgrade for improved denitrification
    ▪ Small upgrade at Williamsburg possible
  – 2021 – 3.4 million pounds/year
    ▪ Upgrade Chesapeake-Elizabeth (full plant)

• Nitrogen – York River ---- No change?
  – Rapid upgrade - denite filters for 2011 compliance
  – Upgrade needed for cost-effective BNR and reliability
HRSD Treatment and BNR R&D Program Focus

• Resource utilization:
  – Energy
  – Chemicals
  – Labor (operations, maintenance, instrumentation…)
  – Concrete

• Resource recovery
  – Water
  – P
  – N (maybe)
  – CH₄ - biogas
  – Heat
  – Hydraulic energy
  – Chemicals of interest (maybe)
  – Biosolids (N, P, organics)
  – Etc, etc, etc
Current HRSD R&D Efforts in BNR:

- Struvite avoidance and recovery (labor, energy, chemicals)
- Mainstream Deammonification & Nitritation-Denitritation (energy, chemicals, concrete)
- Supplemental carbon for denitrification (chemicals)
  - AOB conversion of methane to methanol
  - Reduced S compounds
  - Ethanol used for fuel blending
- Ammonia-based DO control systems (energy, chemicals, concrete)
- Cost-effective chemically enhanced primary treatment (chemicals, energy, concrete)
- Algae-based nutrient removal (chemicals, energy)
- Centrate deammonification = partial nitritation + anammox (chemicals, energy)
- Nitrite accum. and excessive chlorine demand (chemicals)
- IFAS process development and modeling (concrete, energy)
- Nitrification inhibition (concrete)
- Improvement of BNR process models (chemicals, energy, concrete)
- Organic nitrogen sources and fate (issue)
- Urine separation (???)
Global N Cycle – Impact of Haber-Bosch

Gruber & Galloway, 2008
History of Phosphorus-Based Fertilizers

Green Revolution Fueled By Phosphorus Rock

Liebig discovers role of Phosphorus in crop yields

Human excreta, a rich source of phosphorus, have been used by Chinese for 5000 years

US Guano Islands Act encourages Americans to find islands with Guano

Malthus dies

Modern Phosphorus Cycle

- Phosphate Rock Mining
- Fertilizer Production
- Production Wastewater
- Fertilizer Application
- Food Consumption
- Wastewater Treatment
- Return to Environment
Global Distribution of Reserves Raises Questions

Global Reserves (15Gt: R/P=89)

China 27%
Morocco 38%
South Africa 10%
Others 17%
United States 8%

R = Reserves
P = Production
...89 years of reserves

Source: USGS Data on phosphate production October 9, 2007
Disputed Phosphate Reserve Estimate

Global Reserves (60 Gt: R/P = 333)

- Morocco: 76.9%
- China: 5.7%
- South Africa: 2.3%
- USA: 2.2%
- Jordan: 5.3%
- ROW: 7.6%

R = Reserves
P = Production

IFDC Report – September 2010
A bit of background….

- Nitrification-Denitrification
- Biological P Removal
MLE Process (N Removal)

Nitrate/Internal Recycle (IMLR) = Nitrate Recycle (NRCY)

Primary Effluent → Anoxic
BOD + NH₄ → BOD Rem. by Denitrification

Anoxic

Aerobic
Nitrification & Residual BOD Removal

air

TN ~ 8-12 mg/L
4-Stage Bardenpho (Better N Removal)

- Primary Effluent
- BOD + NH₄
- Anoxic
- Nitrate Recycle (NRCY)
- Carbon (Methanol?)
- Aerobic
- Anoxic
- RAS
- Air
- SC
- WAS
- TN ~ 3-5 mg/L
Phosphorus accumulating organisms (PAO’s)
Unique Anaerobic/Aerobic Metabolism

**Anaerobic Conditions**
- Acetate/VFA
- Energy
- $\text{PO}_4^{-3}$

**Aerobic Conditions**
- Energy
- $\text{CO}_2 + H_2O$
- $\text{O}_2$
- $\text{PO}_4^{-3}$
Biological Phosphorus Removal (Bio-P)
Bio-P in A/O Process

A/O Process

ANA = Anaerobic
AER = Aerobic

Addition of an anaerobic selector…
Removal of P Through WAS

- **Typical Mixed Liquor**
  - 1.5 - 2% (P / MLVSS by weight)

- **Bio-P Mixed Liquor**
  - Up to 15-35% (P / MLVSS by weight)
  - 5 - 7% Typ.

- **Lower SRT/MCRT = better Bio-P**
  - Down to about 3 days
Six Key Considerations for Bio-P

- Input of sufficient rbCOD in the form of VFAs to the anaerobic zone.
- Minimization of oxygen and nitrate return to or presence in the anaerobic zone.
- Minimization of post-aerobic P release, either in an over-designed secondary anoxic zone or in the secondary clarifier.
- Operation at solids retention time (SRT) as low as possible (in excess of that required for nitrification).
- DO of ~2 mg/L at head of aerobic zone
- Careful management of solids handling processes and recycle streams.
Add Bio-P to MLE…

A²/O or Phoredox Process

ANA = Anaerobic
ANX = Anoxic
AER = Aerobic
Better P Removal (with Nitrification)

UCT Process

VIP Process

MUUCT Process
The VIP® Process

• It was developed and patented by HRSD, VT, and CH2M Hill
• Biologically removes Phosphorus and Nitrogen
• It's free for any one to use…
5-Stage Bardenpho

Generally - “5-stage BNR”
Add second anoxic zone to a Bio-P processes (for example VIP + 2, MUCT+2, A2O+2, etc)
HRSD Nansemond Plant
Nansemond Plant (pre 2008)
Phosphorus Profile

Values in mg/L TP
What is Struvite?

\[ \text{Mg}^{2+} + \text{NH}_4^+ + \text{PO}_4^{3-} \rightarrow \text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O} \]
How Bad Can it Get?

Centrifuge Bowl Scoring

Pipe Restrictions
Nansemond Treatment Plant Upgrade
What is the Ostara® Process
Ready to Use After Drying, No Post Processing
Pilot Testing

- >80% phosphate recovery
- >42% ammonium recovery
- Higher P removal was achieved at lower pH conditions compared to previous studies
- Good Product quality
  - 2-4mm diameter pellets
Pilot Plant OP Performance

Ortho-Phosphorus Influent and Effluent Concentrations

Average P removal 80%
## Alternatives Cost Analysis

<table>
<thead>
<tr>
<th>Cost Description</th>
<th>Do Nothing</th>
<th>Side Stream Chem Trmt</th>
<th>Ostara</th>
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<tbody>
<tr>
<td>Total Annual Savings</td>
<td>0</td>
<td>0</td>
<td>528,000</td>
</tr>
<tr>
<td>Total Annual Operating Costs</td>
<td>(392,000)</td>
<td>(429,000)</td>
<td>(91,000)</td>
</tr>
<tr>
<td>Net Annual Costs</td>
<td>(392,000)</td>
<td>(429,000)</td>
<td>437,000</td>
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<tr>
<td>Capital Costs</td>
<td></td>
<td></td>
<td>3,926,000</td>
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<tr>
<td>Net Present Worth @ 10 years</td>
<td>(3,027,000)</td>
<td>(3,313,000)</td>
<td>(552,000)</td>
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<tr>
<td>Net Present Worth @ 20 years</td>
<td>(4,885,000)</td>
<td>(5,346,000)</td>
<td>1,520,000</td>
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</table>
Summary of Benefits to Using Ostara Process

• Reduce recycle nutrient loads
• Reduce struvite scale formation
• Reduces phosphate concentration in biosolids
• Reduce sludge volumes (a little)
• Generate a high quality fertilizer that recovers costs
• Stabilize plant bio-P process

Reduced Costs & Improved Reliability
HRSD and Ostara’s Agreement

• 10 year contract with Ostara to purchase all product produced at the facility with increases to purchase price based on the CPI.
• HRSD compensated for materials and operating costs.
• Ostara provides the equipment and process oversight.
• HRSD retains ownership of the building and equipment after contract expires.
• Ostara markets and distributes the fertilizer product under the name as CrystalGreen™. HRSD’s name is not used on any packaging.
Struvite Recovery Facility Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design</th>
<th>Units</th>
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<tbody>
<tr>
<td>Design Flow</td>
<td>110,000</td>
<td>GPD</td>
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<tr>
<td>NH$_4$ Influent Concentration</td>
<td>650</td>
<td>mg/L as N</td>
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<tr>
<td>PO$_4$ Influent Concentration</td>
<td>450</td>
<td>mg/L as P</td>
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<tr>
<td>Proposed No of Reactors</td>
<td>3</td>
<td>500 kg/day</td>
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<tr>
<td>Reactor PO$_4$ Effluent Concentration</td>
<td>72</td>
<td>mg/L PO$_4$-P</td>
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<tr>
<td>PO$_4$ Removal Efficiency</td>
<td>84</td>
<td>%</td>
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<tr>
<td>Mass of Phosphorous Removed</td>
<td>346</td>
<td>Lbs/day</td>
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<tr>
<td>Reactor NH$_4$ Effluent Concentration</td>
<td>479</td>
<td>mg/L NH$_4$-N</td>
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<tr>
<td>NH$_4$ Removal Efficiency</td>
<td>26</td>
<td>%</td>
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<tr>
<td>Mass of Nitrogen Removed</td>
<td>157</td>
<td>Lbs/day</td>
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<tr>
<td>Struvite Production Rate</td>
<td>501</td>
<td>Tons/year</td>
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<tr>
<td>Manpower Requirements (FTE)</td>
<td>0.5</td>
<td>5 days/wk</td>
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</table>
Struvite Facility Layout

- Chemical Reactors
- Chemical Tanks Feed Pumps
- Drying Equipment
- Product Storage
- Silos and Bagging Equipment
Struvite Facility Cost

Project Cost $5.6 M

- Building and Sitework: 40%
- Process Equipment and Technology license: 56%
- Design: 4%

HRSD
Struvite Facility Construction Schedule

- Proposal Submitted July 2009
- Commission Approval October 2009
- Contract Signed November 2009
- Operational May 2010
- Ribbon-cutting May 27, 2010
Complete Ostara System

Crystal Green Storage & Bagging

Dewatering Screen & Dryer

Pearl Reactors

Chemical Storage & Feed
Struvite Recovery Facility Video
Available at White’s Old Mill Garden Center in Chesapeake, VA
# Struvite Recovery Facility Performance

We are currently producing ~1.0 ton/day

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<tr>
<th>Period</th>
<th>PO4-P</th>
<th>NH3-N</th>
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<th></th>
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<tbody>
<tr>
<td></td>
<td>Centrate</td>
<td>Ostrate</td>
<td>% Recov</td>
<td>Centrate</td>
<td>Ostrate</td>
<td>% Recov</td>
</tr>
<tr>
<td>Design</td>
<td>450</td>
<td>72</td>
<td>84</td>
<td>650</td>
<td>479</td>
<td>26</td>
</tr>
<tr>
<td>Dec 2011</td>
<td>440</td>
<td>44</td>
<td>90</td>
<td>787</td>
<td>603</td>
<td>23</td>
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<tr>
<td>YTD</td>
<td>354</td>
<td>44</td>
<td>87</td>
<td>509</td>
<td>385</td>
<td>27</td>
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<tr>
<td>12 Mon Avg</td>
<td>440</td>
<td>44</td>
<td>90</td>
<td>793</td>
<td>609</td>
<td>23</td>
</tr>
</tbody>
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Nansemond BNR Performance

Before Upgrade

After Upgrade

Concentration (mg/L)

Fin Eff Total Phosphorous

Permit Limit: Total Phosphorous (Annual Average)

Fin Eff Total Nitrogen

Permit Limit: Total Nitrogen (Annual Average)
Phosphorous Reduction in Solids

[Graph showing phosphorous reduction in solids over months from January to December. The graph compares 2010 and 2011 data, including average and startup periods. The graph indicates a 26% decrease in phosphorous concentration.]
Lesson’s Learned

1. Locate facility as close as possible to dewatering facilities
2. Avoid pipe “traps” and standard elbows
3. Provide flush connections on all pipe runs
4. Feed CO$_2$ to centrate piping to control struvite
5. Construction sequencing of plant upgrade did impact performance
6. BNR and Digester operations are related to struvite recovery
Next Steps

• Install a permanent CO$_2$ feed system to inhibit struvite formation
• Evaluate WASSTRIP$^\circledR$ process
WASSTRIp Evaluation for Nansemond
SLUDGE SAMPLE PRIOR TO WASSTRIP IMPLEMENTATION SHOWS SIGNIFICANT STRUVITE CRYSTALS

~60 DAYS AFTER WASSTRIP IMPLEMENTATION, DRASTIC REDUCTION IN STRUVITE CRYSTALS
Imhoff cone with washed sludge shows drastic reduction in digester struvite formation.

**Sludge Sample prior to WASSTRIP Implementation with 15 ml/L of struvite crystals**

**~60 days after WASSTRIP Implementation with 1 ml/L of struvite crystals**
HRSD Atlantic Treatment Plant
Current Atlantic Plant
OP - Batch Release Rate Measurements

Graph showing concentration of OP over time for different conditions:
- WAS + 20 gpm APD
- WAS + PS
- WAS + PS+ 20 gpm APD

Y-axis: OP Concentration mg/L
X-axis: Time (hrs)
Mg - Batch Release Rate Measurements

- WAS + PS
- WAS + 20 gpm APD
- WAS + PS+ 20 gpm APD

Graph showing Mg Concentration mg/L over Time (hrs) with lines indicating different conditions.
Conclusions

- Ostara process makes a clean and marketable product from centrate with minimal post processing
- Plant staff are enthusiastic
- WASSTTRIP could eliminate struvite problems and struvite loss in dewatered biosolids
Questions?

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