A Green Alternative for Dissolved Nutrient Recovery in Wastewater Side Streams

Laurissa Cubbage, P.E.
OWEA 2011
Sandusky, OH
Overview

- Nansemond Treatment Plant
- Ostara Process
- Side Stream Treatment at Nansemond
- Economic Evaluation
- Design and Construction
- Startup Data
- Conclusions
Nansemond Treatment Plant
Nansemond Treatment Plant (NTP)

- Hampton Roads Sanitation District (HRSD)
- Suffolk, VA
- 30 mgd facility
- Treated effluent discharges into the James River, ultimately into the Chesapeake Bay
- Currently under construction for 5-Stage BNR upgrade
Project Drivers

- Nutrient objectives
  - HRSD’s Nutrient Compliance Plan Strategy
  - Annual average basis
  - Effluent TN – 8 mg/L
  - Effluent TP – 1 mg/L
- Abnormally high P concentrations
- Frequent bio-P upsets
- Potentially lower limits
## NTP’s Historical Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Historical Influent Annual Average Concentration</th>
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<tbody>
<tr>
<td>BOD, mg/L</td>
<td>243</td>
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<tr>
<td>TSS, mg/L</td>
<td>165</td>
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<tr>
<td>TKN, mg/L</td>
<td>41.1</td>
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<tr>
<td>NH3, mg/L</td>
<td>30.2</td>
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<tr>
<td>TP, mg/L</td>
<td>8.6</td>
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<tr>
<td>Ortho-phosphate, mg/L</td>
<td>6.7</td>
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### Average Effluent Concentration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average Concentration</th>
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<tbody>
<tr>
<td>BOD, mg/L</td>
<td>5.0</td>
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<tr>
<td>TSS, mg/L</td>
<td>8.0</td>
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<tr>
<td>Ammonia, mg/L</td>
<td>1.1</td>
</tr>
<tr>
<td>TKN, mg/L</td>
<td>2.8</td>
</tr>
<tr>
<td>TP, mg/L</td>
<td>0.6*</td>
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</tbody>
</table>

*with chemical addition
Industrial P Load - Smithfield Foods Data

- Significant load contributor
- Extremely unfavorable BOD/TP ratio
- Removing all P from Smithfield would reduce influent TP to 5.8 mg/L
- SFF talking with HRSD to reducing their discharge TP

<table>
<thead>
<tr>
<th>Parameter</th>
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<tr>
<td>COD</td>
<td>mg/L</td>
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<tr>
<td>BOD</td>
<td>mg/L</td>
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<tr>
<td>TSS</td>
<td>mg/L</td>
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<tr>
<td>Ammonia</td>
<td>mg/L</td>
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<tr>
<td>TKN</td>
<td>mg/L</td>
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<tr>
<td>NOx</td>
<td>mg/L</td>
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<tr>
<td>TP</td>
<td>mg/L</td>
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<tr>
<td>COD/BOD</td>
<td>-</td>
<td>2.4</td>
</tr>
<tr>
<td>BOD/TKN</td>
<td>-</td>
<td>5.0</td>
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<tr>
<td>BOD/TP</td>
<td>-</td>
<td>8.0</td>
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</table>
Phosphorus Profile through NTP

Influent and Primary Effluent TP (mg/L)

Effluent TP (mg/L)

Influent TP
PE TP
Effl TP
7 per. Mov. Avg. (Effl TP)
7 per. Mov. Avg. (Influent TP)
7 per. Mov. Avg. (PE TP)
Typical 5-Stage BNR Process Flow Diagram
Side-Stream Treatment

- Two side stream treatment options
  - Ostara
  - Ferric Chloride precipitation

- Typical benefits
  - More consistent primary effluent BOD:TP ratios
  - Lower influent TP to BNR
  - More efficient use of chemicals to remove P when concentrations are high
  - Expect reduction in ferric dosage with Ostara process

- Recommend to equalize centrate in any option pursued
Impact of Smithfield Foods on Side Stream Treatment Design

- Current Influent TP = 1377 lb/day
- Smithfield Foods Load = 450 lb/day
- Smithfield Foods @ 6 mg/l = 100 lb/day
- Recycle Stream Load = 690 lb/day

- Range of Predicted TP in Recycle = 340 – 520 lb/day
- Ostara Design Removes 380 lb/day
Site Under Construction (Spring 2010)
Ostara Process
Ostara’s Process

From Centrate

\[ \begin{align*}
\text{Mg}^{+2} & \\
\text{NH}_4^+ - \text{N} & \\
\text{PO}_4^{3-} - \text{P} & \\
\end{align*} \]

\[\text{Ostara Reactor}\]

External NaOH

External \text{Mg}^{+2}

\[\text{Mg(NH}_4\text{)}\text{PO}_4(s)\]

1 mole \text{Mg}^{+2} = 1 mole \text{NH}_4^+ = 1 mole \text{PO}_4^{3-}

\[0.45 \text{ lbs N/lb P}\]

"Determination of Ferric Chloride Dose to Control Struvite Precipitation in Anaerobic Sludge Digesters" Mamais, Pitt, Jenkins 1994 WER
Ostara Internal Schematic

\[
Mg^{2+} + NH_4^+ + PO_4^{3-} \rightarrow MgNH_4PO_4 \cdot 6H_2O
\]
Ostara Produces a Marketable Product

- Struvite pellets sold as a high quality, slow release, fertilizer CrystalGreen™
Ostara Nutrient Recovery Technologies Inc.

- The first commercial-scale plant began operation in Edmonton, Alberta in 2007
- First installation in the US: Durham, Oregon
- **Second installation in the US**: Nansemond TP
- "Ostara’s proprietary technology helps wastewater treatment systems handle sewage sludge liquids in a way that reduces operating costs, increases overall plant capacity, and produces revenue from byproduct"
  -- Ostara

Ostara’s Pearl® Nutrient Recovery Facility opens at the HRSD’s Nansemond Treatment Plant in Virginia
Side Stream Treatment at Nansemond
Side-Stream Treatment – Ferric Chloride Precipitation

- Ferric chloride addition to centrate equalization tanks (old aerated grit tanks)
- Clarification of phosphorus solids prior to equalization
  - Existing grit removal mechanism will remove heavy solids
- Equalization of centrate required over 24 hours
- Phosphorous will ultimately be dewatered and incinerated in existing facilities
- Utilize existing ferric feed facilities
Side-Stream Treatment: Ostara

- Expected reduction of total ferric needed in main stream
- Steady influent feed to Ostara
- Equalization of centrate required
  - Eliminates spikes in influent TP to BNR
  - Uses existing tankage from previous grit removal facility
- Utilize existing ferric feed facilities to save capital cost
Side-Stream Treatment Evaluation

- Ostara piloted at NTP
  - Resulted in proposal from Ostara, October 2007
  - Expected to remove 90% of P in centrate
    - P in side stream accounts for 25-30% of P load to BNR
  - Expected to remove 30% of Ammonia in centrate
    - N in side stream accounts for 10% of N load to BNR
Side-Stream Treatment – Ostara Configuration
5-stage BNR Predicted Effluent Quality at Maximum Month Load with Side Stream Treatment

Current TP limit is 2.0mg/L  
New TP limit will be 1.0 mg/L

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Winter Configuration (T = 12°C)</th>
<th>Summer Configuration (T = 20°C)</th>
</tr>
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<tbody>
<tr>
<td>Effluent TN (mg/L)</td>
<td>14.6</td>
<td>6.1*</td>
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<tr>
<td>Effluent Ammonia (mg/L)</td>
<td>0.62</td>
<td>0.2</td>
</tr>
<tr>
<td>Effluent TP (mg/L)</td>
<td>0.95</td>
<td>0.8</td>
</tr>
<tr>
<td>Methanol (gpd)</td>
<td>0</td>
<td>1000</td>
</tr>
<tr>
<td>Ferric (gpd)</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>NRCY (mgd)</td>
<td>65</td>
<td>50</td>
</tr>
<tr>
<td>MLSS (mg/L)</td>
<td>3500</td>
<td>3000</td>
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<tr>
<td>Configuration</td>
<td>winter</td>
<td>summer</td>
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*Will vary with amount of methanol added.*
Economic Evaluation
## Comparison of Ostara Proposal Cost

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item</th>
<th>Treatment Fee Option</th>
<th>Capital Purchase Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ferric Chloride Chemical Cost</td>
<td>$ (290,000)</td>
<td>$ (290,000)</td>
</tr>
<tr>
<td>2</td>
<td>Sludge Savings</td>
<td>$ (155,000)</td>
<td>$ (155,000)</td>
</tr>
<tr>
<td>3</td>
<td>Methanol Savings</td>
<td>$ (29,000)</td>
<td>$ (29,000)</td>
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<tr>
<td>4</td>
<td>Oxygen Savings</td>
<td>$ (19,000)</td>
<td>$ (19,000)</td>
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<tr>
<td>5</td>
<td>Ostara Paybacks</td>
<td>$ (87,850)</td>
<td>$ (135,850)</td>
</tr>
<tr>
<td>6</td>
<td><strong>Total Annual Savings</strong>¹</td>
<td>$ (580,850)</td>
<td>$ (628,850)</td>
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<tr>
<td>7</td>
<td>Caustic Cost Allowance</td>
<td>$ 25,000</td>
<td>$ 25,000</td>
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<tr>
<td>8</td>
<td>Ostara Annual Fee</td>
<td>$ 444,000</td>
<td>$ -</td>
</tr>
<tr>
<td>9</td>
<td><strong>Total Annual Operating Cost</strong>²</td>
<td>$ 469,000</td>
<td>$ 25,000</td>
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<tr>
<td>10</td>
<td><strong>Net Annual Savings</strong>³</td>
<td>$ (111,850)</td>
<td>$ (603,850)</td>
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<tr>
<td>11</td>
<td>Building Cost</td>
<td>$ 1,080,000</td>
<td>$ 1,080,000</td>
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<tr>
<td>12</td>
<td>Equipment Cost</td>
<td>$ -</td>
<td>$ 3,063,000</td>
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<td>13</td>
<td><strong>Total Capital Cost</strong></td>
<td>$ 1,080,000</td>
<td>$ 4,143,000</td>
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<tr>
<td>14</td>
<td><strong>Present Worth Operating Costs</strong>⁴</td>
<td>$ (1,505,750)</td>
<td>$ (8,129,160)</td>
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<tr>
<td>15</td>
<td><strong>Net Present Worth</strong>⁵</td>
<td>$ (425,750)</td>
<td>$ (3,986,050)</td>
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¹ Sum of items 1-5  
² Sum of items 7-8  
³ Sum of items 10  
⁴ Present worth cost of line 10 over 20 years at 5% cost of financing  
⁵ Sum of items 13 and 14
Capital Purchase - Division of Responsibilities

**Ostara**
- Provide all equipment
- Maintenance on equipment
- Provide magnesium feed facilities
- Market and sell the finished product
- Paybacks from product sales to HRSD to cover incurred cost
  - Power
  - Chemicals

**HRSD**
- 6300 sf facility to house equipment
- Manpower to operate Ostara
- Caustic feed facilities and chemical (existing)
- Electrical cost of facility
- Equalization
- Back up ferric feed system in equalization basin if Ostara is down
Conclusions from Side-Stream Treatment Evaluation

- Recommend to implement the Ostara process
- Side Stream Quality
  - TN reduction small (2 – 3% of influent load)
  - TP reduction significant (approximately 400 lb/d, or 30% of influent load)
- Recommend HRSD select the capital cost option to improve payback
- HRSD chose to implement the Ostara process, and chose the capital purchase option with funding through the Virginia PPEA process.
Design and Construction
Struvite Recovery Facility

- **Fast Track Design/Construction Schedule**
  - Start of Design – August 2009
  - Beginning of Construction – November 2009
  - Facility Commissioned – April 2010
  - Product production – May 2010

Snow in VA Beach?
Building Construction

- 6440 sf facility
- 40 ft to eave
- Pre-fab metal building
- Electrical/I&C Room

- 3 Reactors installed
- Room for 4th Reactor in future
Struvite Recovery Facility – Nansemond TP
Struvite Recovery Facility – Nansemond TP
Start Up
Ammonia Recovery
Ortho-P Recovery
Lesson Learned

- Unwanted struvite formation
Summary

- **Green** Engineering design for NTP
  - Reduce the nitrogen and phosphorus from side stream process
  - Reduces P spikes to BNR process, which aids Bio-P
- Ostara provides a sustainable “green” alternative to removing phosphorus from this side stream
- Struvite Recovery Facility successfully design and constructed using fast-track semi design-build
- SRF is currently producing **Crystalgreen®**!
Special Thanks

John Dano, P.E.
Bill Balzer, P.E.

Ahren Britton
Aynul Dharas
www.ostara.com

Alan Stone, P.E., Katya Bilyk, P.E., Paul Pitt, P.E.,
Leah Flowers, Hunter Long
Questions?

Creating Value from Waste
Side-Stream Treatment – Ostara
Ostara’s Edmonton Installation
Side-Stream Treatment Cost

- Capital Purchase Option
  - $3.0 million Capital
  - $135,850/yr Credit

- Treatment Fee Option
  - $444,000/yr

- Savings
  - Ferric chloride cost not incurred
  - Sludge treatment and disposal costs
  - Methanol costs not incurred
  - Oxygen cost not incurred
  - Ostara credits

- Costs
  - Caustic chemical
  - Annual fee (treatment option only)
# Ostara Cost Evaluation

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment Fee Option</th>
<th></th>
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<th></th>
<th>Capital Purchase Option</th>
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<td></td>
<td>10 Year Agreement</td>
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<tr>
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<td>$628,850</td>
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<td>Operating Cost</td>
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<tr>
<td><strong>Total Annual Operating Cost</strong></td>
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<td>$409,000</td>
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<td>$409,000</td>
<td>$25,000</td>
<td>$25,000</td>
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<tr>
<td><strong>Net Annual Savings</strong></td>
<td>$(111,850)</td>
<td>$(171,850)</td>
<td>$(171,850)</td>
<td>$(603,850)</td>
<td>$7,525,000</td>
<td>$5,714,000</td>
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<td>Present Worth Savings (5%)</td>
<td>$1,394,000</td>
<td>$2,142,000</td>
<td>$2,142,000</td>
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<td>$7,525,000</td>
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<td>$1,058,000</td>
<td>$1,626,000</td>
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<td>Net Present Worth (5%)</td>
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<td>$546,000</td>
<td>$546,000</td>
<td>$546,000</td>
<td>$1,570,890</td>
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</tbody>
</table>
“Green Engineering is the design, commercialization and use of processes and products that are feasible and economical while: reducing the generation of pollution at the source and minimizing the risk to human health and the environment.”

http://www.epa.gov/oppt/greenengineering/
Crystal Green ™ fertilizer

- Fertilizer for parks and golf courses
- Specialized product
- **Green** attributes
  - Slow release fertilizer
  - Produced with minimal greenhouse gas emissions
  - Renewable source
  - Reduces mining of phosphorus for use in commercial fertilizers
Total Phosphorous Recovery