Refinement of Nitrogen Removal from Municipal Wastewater Treatment Plants

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In partnership with George Miles Buhr, LLC

Prepared for
Maryland Department of the Environment
What is ENR?

- **Enhanced Nutrient Removal**
- **Reduce nutrient discharges from WWTPs**
- **Use of state-of-the-art microbial technology to break down nitrogen before discharge**
- **Next step from BNR**
Biological Nutrient Removal Program (BNR Program)

- Implemented in 1983 by the Maryland Department of the Environment (MDE)
- Included 66 plants of capacity ≥ 0.5 MGD
- Plants retrofitted to achieve total nitrogen limits of 8 mg/l
- Goal was 40% reduction of nutrients to Chesapeake Bay (Bay)
- Have exceeded this goal
- Actual reductions from 1985 levels = 16.9 million pounds

- Clear evidence plants could exceed 8 mg/l
- EPA/MDE/Local Governments looking to achieve further nitrogen reductions cost effectively
- Enhancement of BNR Program in compliance with amended 2000 Chesapeake Bay Agreement by further reducing nutrients to the Bay
- GF/GMB asked to evaluate 20 of the largest WWTPs in MD
- Evaluate alternatives for reducing nitrogen in WWTP effluent
- Develop cost estimate for alternatives
- Extrapolate cost estimate to 66 plants in BNR Program which helped establish newly enacted flush tax
<table>
<thead>
<tr>
<th>PLANT</th>
<th>EXISTING BNR PROCESS</th>
<th>RATED FLOW (MGD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambridge</td>
<td>MLE</td>
<td>8.1</td>
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<tr>
<td>Seneca</td>
<td>MLE</td>
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<td>Piscataway</td>
<td>Step Feed</td>
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<td>Parkway</td>
<td>Bardenpho (4-Stage)</td>
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<td>Schreiber System</td>
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<td>Freedom District</td>
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<td>Johannesburg</td>
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<tr>
<td>Frederick</td>
<td>$A_2$O</td>
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<td>Bowie</td>
<td>$VT^2$</td>
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<td>Cox Creek</td>
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<tr>
<td>Back River</td>
<td>MLE</td>
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<td>Salisbury</td>
<td>Submerged ($A_2$O) Trickling Filter</td>
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<tr>
<td>Hurlock</td>
<td>Bardenpho (4-Stage)</td>
<td>1.65</td>
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</table>
Phase I
Approach

Phase I (2002-2003): Evaluate ways to cost effectively reduce N in plant discharges

Primary considerations in developing alternatives

- developed biological models at each facility to estimate nitrogen removal capacity
  - determined tank (reactor) volume requirements for each plant utilizing industry standards and individual plant data
- site constraints
- existing plant configuration
- cost effectiveness of alternatives

Needed one or two processes that were proven and reliable
Breakdown of BNR Processes in Maryland Phase I Challenge

- MLE: 25%
- A2O: 6%
- Activated Sludge: 15%
- Methanol Addition: 6%
- Oxidation Ditch: 1%
- Overland: 3%
- Lagoon: 7%
- Schreiber: 3%
- Bardenpho: 6%
- RBC: 6%
- Trickling Filter: 3%
- Step Feed: 3%
- 1% of each category
ENR process takes additional time and requires additional tank volume beyond BNR.
Modified Ludzack-Ettinger (MLE Process)

- Anoxic
- Internal Recycle
- Oxic
- Clarifier
- WAS

RAS

Cox Creek WRF, Anne Arundel Co.
15 mgd
A2O Process

- Anaerobic
- Anoxic
- Oxic
- Clarifier

RAS

Internal Recycle

WAS

Sod Run WWTP, Harford Co.
20 mgd
Bardenpho Process

- Demonstrated ability to achieve 3 mg/l
- Least costly option
- Requires existing tank modification or additional tankage
Additional tankage required for Bardenpho
Separate-Stage Denitrification

Denitrification Filters

- Recommended when existing process nearly achieves complete nitrification
- No cost effective space available for additional reactor volume
Phase I
Cost Estimating

◊ Process Equipment
  • Denitrification filters; Blowers; Pumps; Diffusers
  • Obtained manufacturer cost for several plants
  • Extrapolated equipment costs to other plants

◊ Other Costs
  • RSMeans estimating tools

◊ Operation and Maintenance Costs

◊ Factors applied for disciplines
  • Architectural
  • Civil
  • Mechanical
  • Electrical
STUDY METHODOLOGY
TWO PHASES

Phase II (2003-2004)
- Present findings from Phase I to municipalities
- Request current operational data
- Discuss planned expansion activities
- Solicit feedback on report findings
- Update Phase I data, costs and conclusions
PHASE II FEED BACK

- General acceptance of study recommendations
- “One process is not suitable for every plant”
- “Detailed designs need to be performed for every plant”
- “Costs need to be indexed to Engineering News Record (ENR)”
- “Costs for some facilities are too low”
  - I&C
  - Foundation
  - Engineering
Cost Estimates Revisions

- Moved costs for 2002 → Sept. 2004
- Applied 10% to site-limited plants such as Cox Creek and Sod Run
- Added $50/ft² for geotechnical at select plants
- Added methanol systems for each plant
- Added methanol control at plants with denite filters
  - Nitrate analyzers and loop controllers
- Added lift pumping stations at plants with denite filters
Case Study

Existing Ballenger Wastewater Treatment Plant
6.0 mgd

• A₂O Process
• BOD:TKN = 7:1
• Influent Avg. TKN – 38
• Current TN Discharge: 146,100 lbs
• Projected TN Discharge: 54,800 lbs
• Reduction of 91,300 lb/yr
Case Study

Proposed Alternate for Ballenger Wastewater Treatment Plant

Sufficient volume for 4-Stage Bardenpho
- Add partition walls
Increase MLSS 2500 → 3500
- Adequate clarifier capacity
- Adequate pump capacity
Increase IR 200% → 500%
- Add additional IR pumps
Add chemical phosphorus removal
- Adequate FeCl₃ System
Estimated Cost for ENR: $3,800,000
Cox Creek Water Reclamation Facility
Anne Arundel County
15 mgd

- Existing MLE Process
- Insufficient Reactor Volume Available
- No Space for Additional Tankage
- Solution – Denitrification Filter (requires demo of digesters)
- Current TN Discharge: 365,300 lb/yr
- Projected TN Discharge: 136,990 lb/yr
- Reduction of 228,310 lb/yr
Case Study

Cox Creek Water Reclamation Facility
Anne Arundel County
15 mgd

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
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<td>Process Mechanical</td>
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<td>Mechanical</td>
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<td><strong>Subtotal</strong></td>
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<td>Study, Design and Construction Phase Engineering (15%)</td>
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<td>Escalation per ENR Cost Index</td>
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<td>Mobilization</td>
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<td>Construction Contingency (25%)</td>
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<td><strong>Total Estimated Cost</strong></td>
<td><strong>$26,107,000</strong></td>
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<td>PLANT</td>
<td>EXISTING (OR CURRENTLY DESIGNED) BNR PROCESS</td>
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<tr>
<td>-------------</td>
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<tr>
<td>Cambridge</td>
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<td>TOTAL</td>
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Cost per lb. removed | Cost per gal. treated
Avg | $ 5.90 | $ 1.38
Max | $30.29 | $ 4.18
Min | $ 0.55 | $ 0.21

Total Pounds Nitrogen Removed with ENR: 5,714,000
Results
Cost per Gallon of ENR Improvements

ADDITIONAL REACTOR VOLUME REQUIRED

CONVERSION TO BARDENPHO WITHIN EXISTING REACTOR VOLUME

DENITRIFICATION FILTERS
CONCLUSIONS

- Single phase implementation of ENR is most cost effective
- Alternative carbon sources add flexibility
- Independent study required to establish best treatment alternative
- Average costs
  - $5.90 per pound nitrogen removed
  - $1.38 per gallon treated
- Closely matches previous BNR costs
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