Feasibility of Traditional and Emerging Technologies for Treatment and Resource Recovery from Recycle Streams at the Water Reclamation Plants of Metropolitan Water Reclamation District of Greater Chicago

Presented by

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Senior Environmental Research Scientist

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7. Pro-Corp, LLC and Ostara Inc. for screening recycle streams and analyzing data for cost opinions
• Identification of Recycle Streams at Stickney, Calumet and Egan WRPs
• Sampling Locations - Raw Sewage and Recycle Streams
• Sampling Plan
• Estimation of Flow and Characteristics Data of Recycle Streams
• Loadings at Plant Headworks
• Impact on Treatment at SWRP
• Treatment Options and Screening of Technologies
• Feasible Technologies for District WRPs
Identification of Recycle Streams at Calumet, Egan and Stickney WRPs

- Centrate
  - East side lagoon 9 supernatant overflow plus runoff from drying cells
  - West side lagoon 17 supernatant overflow,
  - Gravity tank supernatant overflow
    (Digester feed tank overflow and Gravity concentration feed tank overflow seldom)

- Centrate
  - GBT filtrate
  - Grit Classifier Recycle
  - Filter Backwash

- Pre-centrifuge centrate
  - Post-centrifuge centrate
  - Gravity Concentration tank supernatant overflow
    (Lagoon supernatant via main screen seldom)
Details of Plant Headworks and Recycle Streams at Calumet WRP

- TARP Tunnel
  - Coarse Screens (2)
  - TARP Wetwell (2)
  - Low Level Coarse Screens (1)
  - Raw Sewage Wetwell (1)
  - High Level Coarse Screens (4)
  - Raw Sewage Wetwell (1)
  - South Surge Chamber
  - South Fine Screens (4)
  - South Fine Sewage Wetwell (1)
  - South Surge Chamber
  - South Fine Screens (4)
  - Raw Sewage Wetwell (1)
  - RS Pumps (3)
  - RS Pumps (4)
  - Aerated Grit (6)
  - Overflow to Old 3-Barrel Effluent Conduit [002]
  - 24-h Composite & Discrete Sampler

- Bypass to Little Calumet River [004]
- 24-h Composite & Discrete Sampler
- 24-h Composite & Discrete Sampler
- To PSTs & Grit Dewatering

- TARP Pumps (6)
- TARP Tunnel

- Low Level (Calumet 17A) Interceptor gets
  - Centrate, East Drying Cells, South Lagoons Recycle Flows
- High Level Interceptor
  - Blue Island, Harvey & South Park
  - Harvey - Sludge Conc’n Tanks Overflow & Digester Complex,
  - South Park - N Lagoons,
  - Blue Island - W Drying Cells

- Grit Washings, Tank Drain etc.
SAMPLING LOCATIONS AT EGAN WRP

Grit Classifier
GBT Filtrate
Centrate
Filter Backwash
SAMPLING LOCATIONS AT STICKNEY WRP
SAMPLING LOCATIONS AT PRE AND POST-CENTRIFUGE FACILITIES AT STICKNEY WRP
SPOCTC1 OLD POST CENTRIFUGES
SCTC COMPOSITE CENTRATE
SAMPLING PLAN

• TIME COMPOSITES COLLECTED EVERY 15-MINUTE APART OVER 24-HOUR PERIOD TO MAKE APPROXIMATELY 2 GALLONS AT EACH STATION

• STICKNEY AND CALUMET WRP - ONCE A WEEK (7/30/08-7/29/09)

• EGAN WRP - TWICE A WEEK (8/11/09-9/3/09)
## CHARACTERISTICS OF RECYCLE STREAMS AND RAW SEWAGE AT CALUMET WRP (7/30/08-7/29/09)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw Sewage</th>
<th>Centrate</th>
<th>Gravity Supernatant</th>
<th>Lagoon 9 (East)</th>
<th>Lagoon 17 (West)</th>
<th>Combined Recycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow, MGD</td>
<td>307</td>
<td>0.6</td>
<td>4.0</td>
<td>0.45</td>
<td>0.45</td>
<td>5.5</td>
</tr>
<tr>
<td>BOD$_5$, mg/L</td>
<td>113</td>
<td>139</td>
<td>158</td>
<td>50</td>
<td>118</td>
<td>143</td>
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<tr>
<td>SS, mg/L</td>
<td>148</td>
<td>768</td>
<td>493</td>
<td>99</td>
<td>653</td>
<td>504</td>
</tr>
<tr>
<td>NH$_3$-N, mg/L</td>
<td>10</td>
<td>286</td>
<td>7</td>
<td>80</td>
<td>308</td>
<td>68</td>
</tr>
<tr>
<td>TKN, mg/L</td>
<td>21</td>
<td>495</td>
<td>33</td>
<td>128</td>
<td>487</td>
<td>128</td>
</tr>
<tr>
<td>Tot P, mg/L</td>
<td>5</td>
<td>32</td>
<td>17</td>
<td>11</td>
<td>53</td>
<td>21</td>
</tr>
</tbody>
</table>
### CHARACTERISTICS OF RECYCLE STREAMS AND RAW SEWAGE AT EGAN WRP (8/11/09-9/3/09)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw Sewage</th>
<th>Centrate</th>
<th>Filter Backwash</th>
<th>GBT Filtrate</th>
<th>Grit Classifier</th>
<th>Combined Recycle</th>
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</thead>
<tbody>
<tr>
<td>Flow, MGD</td>
<td>24</td>
<td>0.25</td>
<td>1.8</td>
<td>1</td>
<td>0.12</td>
<td>3.17</td>
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<tr>
<td>BOD₅, mg/L</td>
<td>267</td>
<td>80</td>
<td>13</td>
<td>393</td>
<td>265</td>
<td>148</td>
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<tr>
<td>SS, mg/L</td>
<td>344</td>
<td>695</td>
<td>59</td>
<td>998</td>
<td>286</td>
<td>414</td>
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<tr>
<td>NH₃-N, mg/L</td>
<td>17</td>
<td>277</td>
<td>2</td>
<td>4</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>TKN, mg/L</td>
<td>37</td>
<td>289</td>
<td>7</td>
<td>58</td>
<td>35</td>
<td>46</td>
</tr>
<tr>
<td>Tot P, mg/L</td>
<td>9</td>
<td>23</td>
<td>5</td>
<td>32</td>
<td>9</td>
<td>15</td>
</tr>
</tbody>
</table>

1. Centrate is pumped to Northside WRP
2. Combined recycle concentrations include centrate input
## CHARACTERISTICS OF RECYCLE STREAMS AND RAW SEWAGE AT STICKNEY WRP

(7/30/08-7/29/09)

<table>
<thead>
<tr>
<th>Parameter, MGD or mg/L</th>
<th>Raw Sewage SW+WS</th>
<th>Post centrifuge centrate New</th>
<th>Post centrifuge centrate Old</th>
<th>Pre-centrifuge centrate</th>
<th>Centrate composite</th>
<th>Gravity Concentration Tanks Overflow</th>
<th>Combined Recycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>804</td>
<td>1.4</td>
<td>1.4</td>
<td>10.9</td>
<td>13.7</td>
<td>13</td>
<td>26.7</td>
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<tr>
<td>BOD$_5$</td>
<td>192</td>
<td>79</td>
<td>127</td>
<td>853</td>
<td>1,085</td>
<td>371</td>
<td>677</td>
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<tr>
<td>SS</td>
<td>322</td>
<td>336</td>
<td>452</td>
<td>929</td>
<td>1,307</td>
<td>731</td>
<td>978</td>
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<tr>
<td>NH$_3$-N</td>
<td>15</td>
<td>291</td>
<td>481</td>
<td>20</td>
<td>174</td>
<td>15</td>
<td>83</td>
</tr>
<tr>
<td>TKN</td>
<td>30</td>
<td>332</td>
<td>564</td>
<td>120</td>
<td>266</td>
<td>65</td>
<td>151</td>
</tr>
<tr>
<td>Tot P</td>
<td>6</td>
<td>36</td>
<td>54</td>
<td>45</td>
<td>56</td>
<td>23</td>
<td>37</td>
</tr>
<tr>
<td>WWTP</td>
<td>Flow, m³/d</td>
<td>Centrt Flow, m³/d</td>
<td>%</td>
<td>NH₄-N, mg/L</td>
<td>sCOD</td>
<td>TP, mg Per L</td>
<td>pH</td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------</td>
<td>-------------------</td>
<td>----</td>
<td>-------------</td>
<td>------</td>
<td>-------------</td>
<td>----</td>
</tr>
<tr>
<td>Wards Island, NY, USA</td>
<td>937,500</td>
<td>19,125</td>
<td>2.04</td>
<td>886</td>
<td>431</td>
<td>79</td>
<td>7.7</td>
</tr>
<tr>
<td>Hunts Point, NY, USA</td>
<td>750,000</td>
<td>14,250</td>
<td>1.9</td>
<td>1,312</td>
<td>793</td>
<td>112</td>
<td>7.9</td>
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<tr>
<td>26th Ward, NY, USA</td>
<td>318,750</td>
<td>7,125</td>
<td>2.2</td>
<td>801</td>
<td>494</td>
<td>84</td>
<td>7.8</td>
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<tr>
<td>Bowery Bay, NY, USA</td>
<td>562,500</td>
<td>5,250</td>
<td>0.9</td>
<td>672</td>
<td>371</td>
<td>116</td>
<td>7.5</td>
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<tr>
<td>Kohlfurth, Germany</td>
<td>103,680</td>
<td>300</td>
<td>0.3</td>
<td>628</td>
<td>1,760</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Calumet WRP</td>
<td>1,160,460</td>
<td>2,268</td>
<td>0.2</td>
<td>286</td>
<td>260</td>
<td>32</td>
<td>7.9</td>
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<tr>
<td>Egan WRP</td>
<td>91,098</td>
<td>945</td>
<td>1</td>
<td>277</td>
<td>201</td>
<td>17</td>
<td>7.6</td>
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<tr>
<td>Stickney WRP</td>
<td>3,039,120</td>
<td>10,433</td>
<td>0.3</td>
<td>386</td>
<td>300</td>
<td>11</td>
<td>7.9</td>
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</tbody>
</table>
RECYCLE CONTRIBUTION TO INFLUENT FLOW AT CALUMET WRP (7/30/08-7/29/09)

<table>
<thead>
<tr>
<th>Flow, MGD</th>
<th>307</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD₅</td>
<td>289,323</td>
</tr>
<tr>
<td>SS</td>
<td>378,936</td>
</tr>
<tr>
<td>TKN</td>
<td>53,768</td>
</tr>
<tr>
<td>Tot P</td>
<td>13,314</td>
</tr>
</tbody>
</table>

Loadings in lbs/day

<table>
<thead>
<tr>
<th>% Flow</th>
<th>BOD5</th>
<th>SS</th>
<th>TKN</th>
<th>Tot P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagoon 17 (West)</td>
<td>0.1</td>
<td>0.2</td>
<td>0.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Lagoon 9 (East)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Supernatant</td>
<td>1.3</td>
<td>1.8</td>
<td>4.3</td>
<td>2</td>
</tr>
<tr>
<td>Centrate</td>
<td>0.2</td>
<td>0.2</td>
<td>1</td>
<td>4.6</td>
</tr>
</tbody>
</table>
RECYCLE CONTRIBUTION TO INFLUENT FLOW AT EGAN WRP (8/11/09-9/3/09)

### Loadings in lbs/day

<table>
<thead>
<tr>
<th></th>
<th>Flow, MGD</th>
<th>BOD₅</th>
<th>SS</th>
<th>TKN</th>
<th>Tot P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>24.1</td>
<td>53,573</td>
<td>69,142</td>
<td>7,477</td>
<td>1,809</td>
</tr>
</tbody>
</table>

### % Flow

<table>
<thead>
<tr>
<th></th>
<th>0.5</th>
<th>0.5</th>
<th>0.4</th>
<th>0.5</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grit Classifier Recycle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GBT Filtrate</td>
<td>4.1</td>
<td>6.1</td>
<td>12</td>
<td>6.5</td>
<td>14.7</td>
</tr>
<tr>
<td>Filter Backwash</td>
<td>7.5</td>
<td>0.4</td>
<td>1.3</td>
<td>1.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Centrate</td>
<td>1</td>
<td>0.3</td>
<td>2.1</td>
<td>8</td>
<td>2.6</td>
</tr>
</tbody>
</table>
### Recycle Contribution to Influent Flow at Stickney WRP (7/30/08-7/29/09)

**Flow, MGD**: 804

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flow</th>
<th>BOD&lt;sub&gt;5&lt;/sub&gt;</th>
<th>SS</th>
<th>TKN</th>
<th>Tot P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity Concentration Tanks Overflow</td>
<td>1.6</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Centrate composite</td>
<td>1.7</td>
<td>10</td>
<td>7</td>
<td>15</td>
<td>17</td>
</tr>
</tbody>
</table>

**Loadings in lbs/day**

- **BOD<sub>5****: 1,289,469
- **SS**: 2,157,382
- **TKN**: 202,401
- **Tot P**: 36,861
• Black & Veach 2000 GPS-X – No recycle lines
• Modifications – recycle lines to headworks or final outfall via sidestream treatment unit
• Baseline data correspond to study period with plant and LIMS data and calibrated throughout the process train based on 100% recycle to headworks
• Added a DO controller to evaluate potential energy savings due to aeration
• Each scenario consisted of three 100-day simulations to assure stability
## STICKNEY GPS-X BASELINE MODEL: 100% RECYCLE TO HEADWORKS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>WS Influent</th>
<th>SW Influent + TARP</th>
<th>All Recycle</th>
<th>Final Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow, MGD</td>
<td>431</td>
<td>340</td>
<td>26</td>
<td>772</td>
</tr>
<tr>
<td>SS, mg/L (tpd)</td>
<td>150 (270)</td>
<td>530 (809)</td>
<td>988 (108)</td>
<td>4.8 (15.5)</td>
</tr>
<tr>
<td>CBOD₅, mg/l (tpd)</td>
<td>77 (139)</td>
<td>169 (258)</td>
<td>332 (36)</td>
<td>1.5 (4.9)</td>
</tr>
<tr>
<td>TKN, mg/L (tpd)</td>
<td>19 (34)</td>
<td>47 (71)</td>
<td>156 (17)</td>
<td>0.9 (3.0)</td>
</tr>
<tr>
<td>TP, mg/L (tpd)</td>
<td>4 (6)</td>
<td>9 (14)</td>
<td>37 (4)</td>
<td>0.8 (1.2)</td>
</tr>
<tr>
<td>NH₃-N, mg/L (tpd)</td>
<td>10 (18)</td>
<td>19 (29)</td>
<td>94 (10)</td>
<td>0.1 (0.2)</td>
</tr>
</tbody>
</table>
Stickney GPS-X Model: Sludge Production as a Function of Percent Recycle to Headworks

% Recycle to Headworks

Sludge Production, tpd
Normal plant operation: 496 x 10^6 cft/day & aeration energy 368 MWH/day

DO control set point of 4.5 mg/L. Results in ~15% savings
1. Maintain Present Operation
2. Recirculate But Equalize the Flows
3. Use As a Liquid Fertilizer
4. Remove or Recover Nutrients
OPTION 2: CONCEPTUAL REPRESENTATION OF RECYCLE FLOW EQUALIZATION

Sidestream Control Impacts Effluent Quality

Average effluent NH$_3$N = 0.86 mg/L with equalized sidestream return.

Average effluent NH$_3$N = 0.50 mg/L with controlled sidestream return at night during low influent loads.
OPTION 3: LIQUID FERTILIZER (N:P :: >5 to 1)

- A total of 18 MGD (37% flow) from 7 streams out of 13

- Benefits to the Environment
  - Conserve water/phosphate reserves
  - Recycle materials locally
  - Avoid greenhouse gas emissions (~8 tons CO$_2$e per ton fertilizer produced)
  - Environmental Sustainability

- Drawbacks
  - Transport based on volume required
  - Heavy metals

TKN, mg/L inside the bar:
- Calumet Centrate: 495 mg/L
- Egan Centrate: 289 mg/L
- Lagoon 9 (East): 128 mg/L
- Post centrifuge centrate Old: 564 mg/L
- Post centrifuge centrate New: 332 mg/L
- Lagoon 17 (West): 487 mg/L
- Stickney Centrate Composite: 266 mg/L
OPTION 3: AN OFFICIAL SEAL OF APPROVAL FOR LIQUID FERTILIZER
OPTION 4A: TREAT TO REMOVE NUTRIENTS. WHY?

OPTION 4B: TREAT TO RECOVER NUTRIENTS. WHY?
Option 4A: Why to Treat Recycle Streams?

1. Stringent Regulatory Limitations
   - TP (Water Quality)
   - TN (Water Quality)
   - Nitrate (SDWA)
   - NH$_3$-N (NPDES for Aquatic Toxicity)
   - Bottle-necks in Permit (Daily Max, Wkly Avg. etc.)

2. Sustainable Treatment for Nutrient Removal & Entire Plant
   - Requires less energy (reduction in C footprint)
   - Increases Process Capacity at Low Temperatures

3. Common Treatment for Multiple Plants
   - More TP and TN @ SWRP from NSWRP/EWRP
   - Less Capital & OM Costs
   - Reliable Operations @ One Location than Two Small-scale Operations

4. Adjustment in Plant Operations
   - Variable Thickening and Dewatering Process Schedule
   - Impact if Only One Shift or Certain Days (HPWRP, CWRP)
   - Increased use of BNR
   - Major Plant Upgrade (e.g. Master Plan)
Phosphorus Supply Challenges

Nutrient Recovery from a global perspective (7 billion humans and 63 billion live stock)

1.5% mining of rock phosphate can be reduced if P recovery around the world (Shu et. al. 2006)

“We may be able to substitute nuclear power for coal, and plastics for wood, and yeast for meat, friendliness for isolation – but for phosphorus there is neither substitute nor replacement” Isaac Asimov

Conserve phosphate reserves, recycle P locally, reduce GHGs and environmentally sustainable
Phosphorus is an “Emerging Issue”

From the June 2008 Scientific American Magazine | 20 comments
Phosphorus Famine: The Threat to Our Food Supply
This underappreciated resource—a key component of fertilizers—is still decades from running out. But we must act now to conserve it, or future agriculture could collapse

By David A. Vossel

From The Times
June 23, 2008
Scientists warn of lack of vital phosphorus as biofuels raise demand
Leo Lewis, Asia Business Correspondent

NEWS SCAN
Scientific American – November 2009
Technology
Sewage’s Cash Crop
How flushing the toilet can lead to phosphorus for fertilizers
By KATHERINE TWEED

Tucked away in Oregon’s Willamette Valley, three massive metal cones could help address the world’s dwindling supply of phosphorus, the crucial ingredient of fertilizers that has made modern agriculture possible. The cones make consistently high-quality, slow-release fertilizer pellets from phosphorus recovered at the Durham Advance Wastewater Treatment Facility, less than 10 miles from downtown Portland. By generating about one ton

WASTEWATER WONDER: Ostara’s Crystal Green, a slow-release fertilizer, incorporates phosphorus retrieved from sewage streams.
Treatment Technologies for Options 4A and 4B
TREATMENT TECHNOLOGIES

Biological

- CND
- AND : Bioaugmentation w/ and w/o RAS (In-Nitri, BABE, BAR etc.)
- Nitritation/Denitritation and Deammonification (SHARON, ANNAMOX, SBR, STRASS, MAUREEN, OLAND, CANON etc.
- Algae Based (stabilization/oxidation ponds, Algaewheel®, Algal Turf Scrubber® Technology, Algae farms)

Physicochemical

- Ammonia Stripping (ARP via Steam, Hot Air, & CAST Vacuum Distillation)
- IE
- MAP based technologies (Metal Salts, Ostara, Pro-Corp)
SCREENING OF TECHNOLOGIES

- **CND**: Alkalinity deficiency 25, 88, 82% at CWRP, EWRP and SWRP, respectively, impact on aeration cost, ammonia toxicity etc.

- **Bioaugmentation**: pH, temp, TDS/osmotic pressure changes in main treatment so augmented nitrifiers predated

- **Nitritation/Denitritation/Deammonification**: Many premature and emerging technologies - not suitable for full-scale of District plants

- **Algae Based**: Settling and possible SS violation, premature for full-scale, polymer costs

- **Air Stripping**: 2000:1 Air to NH3 ratio, pH ~11, ~55C air temp – pH and temp control, scaling etc.

- **Steam Stripping**: Heat exchanger & stripper fouling, 300 - 500 to 1 steam to liquid ratio, high temp maintenance and associated energy cost

- **IE**: Pretreatment such as filtration needed, salt deposits within resin bed, piping etc.
• CND: Alkalinity – 7.14 g/g NH4
  : O2 – 4.57 g/g NH4
  : C – 3 to 4.5 g COD/g of NO3

Nitritation/Denitritation:
  : O2 – 25% less wrt CND
  : C – 40% less so 40% less biomass

• Deammonification:
  : O2 – 62% less wrt CND
  : C – 100% less so much reduced biomass
  : Reduced CO2 and N2O
Features:

- At 25-40 °C the nitrifying bacteria have a higher growth rate than the nitrafying bacteria.
- pH 6.6 to 7.2 for AOBs and DO 0.3 to 2 mg/L
- SRT=HRT
- At a 1 day SRT/HRT the reactor acts as a selector converting ammonia to nitrite
- The process then allows for denitrification via nitrite.

BIOLOGICAL GROWTH RATE – $SRT_{MIN}$ AS A FUNCTION OF TEMPERATURE

![Graph showing Min. SRT (day) vs Temperature (°C)]

- Nitrosomas
- Nitrobacter

Min. SRT (day)

0 1 2 3 4 5

Temperature (°C)

0 10 20 30 40
<table>
<thead>
<tr>
<th>Location</th>
<th>Capacity (pe)</th>
<th>(lbs N/day)</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utrecht, Netherlands</td>
<td>400,000</td>
<td>2000</td>
<td>1997</td>
</tr>
<tr>
<td>Rotterdam-Dokhaven</td>
<td>470,000</td>
<td>1900</td>
<td>1999</td>
</tr>
<tr>
<td>Zwolle</td>
<td>200,000</td>
<td>900</td>
<td>2003</td>
</tr>
<tr>
<td>Beverwijk</td>
<td>320,000</td>
<td>2,600</td>
<td>2003</td>
</tr>
<tr>
<td>Groningen-Garmerwalde</td>
<td>300,000</td>
<td>5,300</td>
<td>2004</td>
</tr>
<tr>
<td>Den Haag-Houtrust</td>
<td>430,000</td>
<td>2,900</td>
<td>2004</td>
</tr>
<tr>
<td>New York-Wards Island</td>
<td>250 MGD</td>
<td>12,700</td>
<td>2008</td>
</tr>
<tr>
<td>Geneva, Switzerland</td>
<td>115 MGD</td>
<td>3,600</td>
<td>2009</td>
</tr>
</tbody>
</table>
WARDS ISLAND, NEW YORK
SHARON PLANT

Goals:
• To reduce TN discharge from the Wards Island facility into the East River/Long Island Sound/NY Harbor
• To reduce TN discharge associated with the solids handling at multiple NYC-DEP facilities
• To utilize a highly efficient process for cost savings associated with TN
Two Parallel SHARON Reactor Trains:

Design / Peak Flow: 1.85 / 2.31 MGD
NH₃: 700 mg/l
   10,800 lbs./day
   (~30% N-Load)
TSS: 600 mg/L
COD: 950 mg/L
Temp.: 28 – 32 C
N-Removal: >95%

Benefits:
- Removes 25-35% of ammonia load to main stream nitrification tanks. Over 2.5 tpd TN removed.
- Reduces oxygen required for nitrification by 25%. Lowering both capital and M&O costs.
- Reduces methanol required for denitrification by 40%. Lowering both capital and M&O costs.
- Reduces the size of main stream reactors, especially associated with respect to denitrification processing.

WARDS ISLAND, NEW YORK – 250 MGD
Solids from 3 Plants
First in the USA and the largest in the world
Wards Island SHARON® System

Influent -> NH₄ -> NO₂ -> N₂

Effluent

RAS/WAS WETWELL BATTERY C, D, E

4 HX Pumps HX Building

4 PLE Pumps FST AT-13

Heat-exchanger

6 Blowers Blower Building

BNR Chemical Storage Building

Methanol Storage

C-source

Aeration

Courtesy of Mr. Keith Beckmann, P.E., Chief - Process Planning of NYCEP, NEW YORK
ANaerobic AMMonium OXidation Process

• Observation of simultaneous removal of NH$_4$-N and production of N$_2$ in the Netherlands in 1986 led to ANAMMOX technology.

• A derivative of SHARON process - ANAMMOX bacteria/autotrophic bacteria accomplish N-removal during nitrification & denitrification.

• NH$_4$-N is used as an electron donor in lieu of organic carbon source such as methanol.

• 50% of NH$_3$-N is oxidized to NO$_2$-N in a SHARON reactor and equal ratio of NH$_4$-N to NO$_2$-N liquor is sent to the second ANAMMOX reactor, where the ANAMMOX bacteria reduce nitrite to N$_2$.

• Both processes can take place in a single reactor where two guilds of bacteria form compact granules (Kartal et. al. 2010).

Enriched culture of anaerobic ammonium oxidizing bacteria (Radboud University Nijmegen) Kinestetika 20:44, 15 August 2007 (UTC)
• 62% Reduction in O2 wrt conventional nitrification to nitrate

• No organic carbon needed for denitrification

• Reduced biomass production

• Operating costs reduction by 90% compared to CND (van Loosdrecht, 2004)

• Reduction in GHG gases by 95% possible because of the consumption of CO₂ and a lack of production of nitrous oxide (N₂O)

• N₂ gas can partially mix the contents which can reduce the mixing energy needs

• Sustainable process wrt economic and operational perspectives
**ANAMMOX Process Full-scale Applications and Challenges**

- The DCWASA, City of Baltimore and the NYCDEP spent considerable effort on this technology, DCWASA under design stage for sidestream.

- As of 2010, 20 installations in Europe and 2 in design in the US.

- A full-scale test for raw sewage to begin in Strass Austria and pilot-scale at HRSD.

  - Very slow growth rate of ANAMMOX bacteria need 100 to 200 days after initial seeding to reach full capacity and produce low sludge production. Due to slow growth rate, sludge retention is very important and typical SRT is 1.5 to 2 days.

  - Higher nitrite concentration for extended period of time is detrimental to ANAMMOX bacteria.

  - Challenge is to make it suitable for the treatment of wastewater with lower nitrogen concentrations and low temperatures.
CASTion – A subsidiary of ThermoEnergy

Proprietary tech for recovery of chemicals and water in many industries including WRPs

Up to 40% NH₃ recovery as NH₄SO₄

Flash Vacuum Distillation

- Atomizer
- Low Vacuum

Continuous or batch

Physical principles
- Uses partial pressures to separate materials
- Uses sensible heat of wastewater to increase efficiency

Combined with other technologies (IE, MBR etc) depending on application

Key Variables: pH (10 to 12), feed temp (90 to 120 F, pressure –ve 26 to 29”, process time 6 to 12 min, recirculation rate 15 to 30 turnovers
CASTion PILOT-SCALE RESULTS

- Midsized Aberdeen, WA filtrate: 80% of initial NH₃ of 550 ppm in 7 min at 11.5 pH and T 100 to 120 F

- NYCDEP 26th Ward centrate pilot tests: 80% of initial NH₃ of 815 ppm in 3 min at >12 pH and T 90 F

- Also maintained <100 ppm effluent NH₃ from the initial 550 ppm for 28 min at 11.2 to 11.4 pH and T 100 F

- 1.2 MGD centrate CASTion project at 26th Ward plant to begin Qtr 2, 2010.

- City of Tacoma, WA is to start on-site pilot tests for $50,000 (Off-site tests for $3 to 4000)

Benefits and Drawbacks / Limitations:

- + Potential for substantial reduction in methanol requirement for BNR because it returns alkalinity and COD for BNR

- - Filters, IE pretreatment, pH and temp increase make it costly depending upon centrate quality
**STRUVITE – A BUILDING BLOCK FOR MAP BASED TECHNOLOGIES**

\[
\text{NH}_3 + \text{PO}_4 + \text{Mg} + 6 \text{H}_2\text{O} \rightarrow \downarrow \text{NH}_3\text{PO}_4\text{Mg} \times 6 \text{H}_2\text{O}
\]

- pH dependent, pH pushes the reaction. \(\text{CO}_2 \uparrow = \text{pH} \uparrow = \text{struvite} \downarrow\)
- Removes equi-molar ammonia and phosphorus
- AKA: Struvite, MAGamp, MAP
- Mg limiting element

1 kg of struvite can be recovered from 100 m\(^3\) wastewater & applied on 2.6 ha arable land (Shu L. et. al.)
MAP Based Technologies for P Recovery from Resource Streams

OSTARA & PROCORP, LLC
PEARL™ Process Operation

Pilot-scale Prills  Full-scale Prills
PREFERRED APPLICATION

• Plant size >5 MGD
• Plant processes:
  • Anaerobic zone (Bio–P)
  • Anoxic zone for denitrification/biological selectors
  • Anaerobic digestion & dewatering
• PEARL™ process feed stream desired characteristics:
  • \( \text{PO}_4^-\text{P} \ > 75 \text{ mg/L, and } > 140 \text{ lbs/day for } 90\% + \text{ P removal} \)
  • TSS <1000 mg/L
• Struvite and/or vivianite formation challenges
• <10 Year Payback / Instant Net Savings
• At present, not feasible at District plants but may become feasible with Bio-P treatment
OSTARA TREATMENT AT DISTRICT WRPS

• NOT FEASIBLE DUE TO LOW P

• BIO-P IS A MUST

• IN ORDER TO REALIZE CASH FLOW, NEEDS AT LEAST 2 TO 3 TIMES HIGHER P IN CENTRATE
<table>
<thead>
<tr>
<th>Recycle</th>
<th>Fertilizer, tpd</th>
<th>NH₃, lbs/day</th>
<th>TP, lbs/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWRP Pre-Centrate</td>
<td>6</td>
<td>740</td>
<td>1600</td>
</tr>
<tr>
<td>SWRP Pre &amp; Post Centrate</td>
<td>11</td>
<td>1500</td>
<td>2700</td>
</tr>
<tr>
<td>EWRP Centrate + Filtrate</td>
<td>0.33</td>
<td>46</td>
<td>83</td>
</tr>
<tr>
<td>CWRP Centrate</td>
<td>0.2</td>
<td>26</td>
<td>48</td>
</tr>
<tr>
<td>CWRP Lagoon 9 (Not enough P)</td>
<td>___</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>Lagoon 17</td>
<td>0.4</td>
<td>48</td>
<td>87</td>
</tr>
</tbody>
</table>

If Iron is not added at EWRP, more P will be available, potentially up to 75% of TP.
A SUMMARY OF TREATMENT TECHNOLOGIES FOR FURTHER CONSIDERATION AT DISTRICT WRPS

• SHARON-ANAMOX process for SWRP

• Consider CASTion based on cost economics if excess recovered by-product can be sold in Chicago markets

• Consider MAP Based Technology if Bio-P is implemented: Ostara or ProCorp LLC

• Keep eye on Algalwheel success
THE NEXT STEP

• Need for data on flow and characteristics of recycle streams

• Due to limited supply of P, P-resource recovery from recycle streams in future may become more attractive

• Identify and evaluate feasibility of select technology (e.g. SHARON-ANAMMOX at SWRP) at a pilot-scale
THANKS FOR YOUR ATTENTION

• Questions and/or Comments Now?
• Later? kamlesh.patel@mwrdd.org
  • 708-588-3735
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11. AlgalWheel® Technology Website and Personal Talk at 31st Annual IWEA Conference & Exhibition, 1-3 March 2010 in East Peoria, IL
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