Pilot Scale Membrane Bioreactor Study at King County

Amanda McInnis
Bob Bucher
Susan Anderson
J.B. Neethling
King County Water Reuse Pilot Facilities
MBR Trains

1. Headworks → Membrane BioReactor (nitrification only) → Disinfect
   - Class A
   - All streams

2. Headworks → Membrane BioReactor (BNR) → Disinfect
   - Class A
   - All streams
   - All groundwater
MBR Trains

- Class A
- Wetlands
- All streams
- All groundwater
- All lakes

Headworks → MBR (nitrification) → Reverse Osmosis → Disinfect

Headworks → MBR (BNR) → Reverse Osmosis → Disinfect
Conventional Treatment

Influent → Aeration Basin → Secondary Clarifier

RAS ↔ MLSS
What Is a Membrane Bioreactor (MBR)?

Aeration Basin  |  Membrane Tank

Influent

RAS=MLSS

Vacuum Pump
Presentation Overview

- Study overview
- Turbidity removal
- Peaking performance
- Membrane Cleaning
- Nitrogen Removal
- Phosphorous Removal
- Coliform removal
- Operation at Low SRT
## Pilot Study Overview

<table>
<thead>
<tr>
<th>Process Goal</th>
<th>Actual Aerobic TSA (days)</th>
<th>Actual Total TSA (days)</th>
<th>Average Flow (gpm)</th>
<th>Average Flux * (gfd)</th>
<th>Relax mode or Backpulse mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/dN</td>
<td>--</td>
<td>--</td>
<td>5.4</td>
<td>11.7</td>
<td>Relax 8/29-9-13</td>
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<tr>
<td>N/dN</td>
<td>10.0</td>
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<td>5.3</td>
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<td>Backpulse 9/14</td>
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<td>N/dN</td>
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<td>15.0</td>
<td>7.4</td>
<td>16.1</td>
<td>Backpulse 11/16-12/2</td>
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<tr>
<td>N/dN</td>
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<td>--</td>
<td>5.5</td>
<td>12.0</td>
<td>Relax 12/3</td>
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<tr>
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<td>8.5</td>
<td>5.5</td>
<td>12.0</td>
<td>Relax</td>
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<tr>
<td>N/dN</td>
<td>--</td>
<td>--</td>
<td>5.5</td>
<td>12.0</td>
<td>Relax</td>
</tr>
<tr>
<td>Bio-P</td>
<td>--</td>
<td>--</td>
<td>5.5</td>
<td>12.0</td>
<td>Relax</td>
</tr>
<tr>
<td>Bio-P</td>
<td>6.1</td>
<td>7.4</td>
<td>7.8</td>
<td>16.9</td>
<td>Relax</td>
</tr>
</tbody>
</table>
Process Overview

![Graph showing process overview with phases and days vs. mg/L, phase markers include Startup, Phase 1a, Phase 1c, Phase 2a, Phase 2b, Phase 3a, Phase 3b.](image)

- MLSS-Aerobic Tank
- Total TSA
- Aerobic TSA
Turbidity Performance

Effluent Turbidity  Temperature Corrected Flux (20 deg C)
Turbidity Performance

- Produced consistently low (<0.02 NTU) effluent turbidities, even under peak flow conditions.
4-hour Peaking Test

Graph showing the changes in Dissolved Oxygen, Pressure Before Backpulse, Pressure after Backpulse, and Turbidity over time from 6 AM to 1 PM at flow rates of 6 gpm, 9 gpm, and 8 gpm. The graph indicates an increase in Dissolved Oxygen and Pressure Before Backpulse with time, while the Pressure after Backpulse remains relatively constant. Turbidity shows a decrease after the turbidity probe was removed.
Peaking Performance

- System operated for 22 days at an avg flux of 20 gfd with effluent turbidity avg 0.02 NTU.

- The system responded well to (3) 4-hour peaking tests where flux was increased to >20 gfd.

- Effluent turbidities remained constant in the peaking tests with effluent turbidities 0.01 to 0.03 NTU.
Membrane Cleaning

- Relax Mode
- Backpulse Mode
- Relax Mode

Performed
Disinfection Clean
10/15

Performed
Maintenance Clean

Stopped Maintenance Cleans

- Pre-Backpulse/Relax Vacuum
- Post Backpulse/Relax Vacuum
- Temperature Corrected Flux (20 deg C)
## Nitrogen Removal

<table>
<thead>
<tr>
<th>Process Goal</th>
<th>Actual Total TSA (days)</th>
<th>Average Flux (gfd)</th>
<th>Effluent NH4 (mg/L)</th>
<th>Effluent NO3 (mg/L)</th>
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<tr>
<td>N/dN</td>
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<td>11.7</td>
<td>0.04</td>
<td>6.93</td>
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<tr>
<td>N/dN</td>
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<td>11.5</td>
<td>0.03</td>
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<td>N/dN</td>
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<td>12.0</td>
<td>0.31</td>
<td>5.23</td>
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<tr>
<td>N/dN</td>
<td>8.5</td>
<td>12.0</td>
<td>0.02</td>
<td>7.42</td>
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<td>12.0</td>
<td>0.02</td>
<td>9.37</td>
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<td>Bio-P</td>
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<td>12.0</td>
<td>0.02</td>
<td>8.52</td>
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<tr>
<td>Bio-P</td>
<td>7.4</td>
<td>16.9</td>
<td>0.34</td>
<td>9.53</td>
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## Phosphorous Removal

<table>
<thead>
<tr>
<th>Process Goal</th>
<th>Actual Total TSA (days)</th>
<th>Average Flux (gfd)</th>
<th>Effluent TP (mg/L)</th>
<th>Effluent Ortho-P (mg/L)</th>
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<td>3.64</td>
<td>2.90</td>
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<tr>
<td>N/dN</td>
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<td>11.5</td>
<td>1.62</td>
<td>1.39</td>
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<tr>
<td>N/dN</td>
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<td>16.1</td>
<td>0.52</td>
<td>0.97</td>
</tr>
<tr>
<td>N/dN</td>
<td>8.5</td>
<td>12.0</td>
<td>0.62</td>
<td>0.52</td>
</tr>
<tr>
<td>N/dN</td>
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<td>12.0</td>
<td>0.73</td>
<td>0.72</td>
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<tr>
<td>N/dN</td>
<td>7.4</td>
<td>12.0</td>
<td>1.09</td>
<td>1.00</td>
</tr>
<tr>
<td>Bio-P</td>
<td>--</td>
<td>12.0</td>
<td>0.95</td>
<td>0.92</td>
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<tr>
<td>Bio-P</td>
<td>16.9</td>
<td>0.97</td>
<td>0.92</td>
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</table>
Phosphorous Removal

- Unit was **not designed** for biological P removal.
- Did not meet removal goals
- No improvement in removal when process was modified for bio-P
Coliform Removal

• During Start-up, effluent total Coliform concentrations were as high as $1.7 \times 10^3$ CFU/100 mL.

• Effluent Coliform levels dropped in later phases and no Coliform was detected for the remainder of the study.
Operation at Low SRT

- The system operated successfully at a total SRT of 8 days and an aerobic SRT of 6 days for >3 months.

- The system did not have operation difficulties with high vacuum pressures.
Operation at Low SRT

- Complete ammonia removal (<0.02 mg/L) was achieved.

- Low effluent turbidities (0.02 NTU average) were achieved during the low SRT period.
Reverse Osmosis (RO)

- Four months of operation
- Feed trials
## Reverse Osmosis (RO)

<table>
<thead>
<tr>
<th>Issue</th>
<th>Pilot Experience</th>
</tr>
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<tbody>
<tr>
<td>Performance</td>
<td>TDS &lt; 120 mg/L (&gt;92%)</td>
</tr>
<tr>
<td></td>
<td>TOC &lt; 1.6 mg/L (83%)</td>
</tr>
<tr>
<td></td>
<td>NH4-N &lt; 0.02 mg/L (&gt;90%)</td>
</tr>
<tr>
<td></td>
<td>NO3-N &lt; 0.2 mg/L (&gt;97.5%)</td>
</tr>
<tr>
<td></td>
<td>TP &lt; 0.02 mg/L (&gt;99%)</td>
</tr>
<tr>
<td></td>
<td>Metals &lt; MDL</td>
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<tr>
<td>Startup</td>
<td>Immediate</td>
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<tr>
<td>Flux</td>
<td>9 gfd</td>
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</table>
Acknowledgement

- King County Technology Assessment Program
- West Point Treatment Plant Process Group
- West Point Treatment Plant Process Laboratory
- King County Environmental Laboratory
- West Point Treatment Plant O & M Staff
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- B&V (Cindy Wallis-Lage)
- Zenon Environmental, Inc.