Energy Use at MBRs and Jefferson County’s Port Hadlock MBR Treatment Plant

Jim Santroch, P.E. & Raymond Vargas, P.E.
Port Hadlock - Presentation Outline

- Project Background
- WA Energy Audit requirements
- Review MBR energy use
- Port Hadlock 30% design
- Port Hadlock energy estimate
- Conclusions
Port Hadlock – Project Background

- GMA growth area in Jefferson County WA
- Currently on septic tanks
- 2008 WW Facility Plan
- 2009 MBR equipment bid
- 2011 30% design
- 2012 State & Federal funding
- 2012 VE & IGEA
WA PWTF requirement, also for WA DoC grants

Origins in ASHRAE for Building Energy Management

Audit requires detailed energy analysis & baseline
  - No energy baseline for MBRs
  - No examples for new WWTP designs
  - Some examples for WWTP upgrades

VE study approved as alternate to IGEA for Port Hadlock
Port Hadlock - IGEA
Energy Baseline Analysis

- Published papers on WWTP & MBR energy use
- MBR Manufacturer’s information
- Local MBR plant data
- EPA Energy Star web site
CAS - Conventional Activated Sludge
NY State ERDA - 2008

Table 10
Electric Energy Use by Secondary Treatment Technology: Flow-based

<table>
<thead>
<tr>
<th>Size Category</th>
<th>Activated Sludge (kWh/MG)</th>
<th>Fixed Film (kWh/MG)</th>
<th>Lagoons (kWh/MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1 MGD</td>
<td>4,100</td>
<td>3,600</td>
<td>2,530</td>
</tr>
<tr>
<td>1 to 5 MGD</td>
<td>1,340</td>
<td>1,380</td>
<td>2,170 (^1)</td>
</tr>
<tr>
<td>5 to 20 MGD</td>
<td>1,570</td>
<td>1,140</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>20 to 75 MGD</td>
<td>1,630</td>
<td>1,060</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Greater than 75 MGD</td>
<td>1,070</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
</tbody>
</table>

\(^1\) The value shown is based on data from only two facilities, both of which serve multiple Significant Industrial Users representing 30 to 60% of the flow treated. In addition, one of the lagoon WWTPs is required to provide tertiary treatment.

Source: “Statewide Assessment of Energy Use by the Municipal Water and Wastewater Sector”, November 2008, New York State Energy Research and Development Authority
9-Membrane BioReactors
HDR Report - 2010

- Total plant energy use
- kWh/MG decreases as flow increases

Figure 15: MBR Energy Usage in kWh/MG as a function of flow from Fowler, Dundee, Pooler, Varsseveld, Delphos, Cauley Creek, Healdsburg, LOTT and Bonita Springs. S = Siemens, Z = Zenon, K = Kubota

Source: “MBR Energy Consumption: Comparing Operating Full-Scale Plants”, copyright WEF 2010, Marie-Laure Pellegrin, PhD, and David J. Kinnear, PhD, PE — HDR Tampa, FL
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Membrane BioReactors
GE/Zenon Report - 2011

Total Plant Power Consumption

- Oxford Conventional
- Oxford MBR Today
- Oxford MBR - Future
- Cleveland Bay Conventional
- Cleveland MBR Today
- Cleveland Bay MBR - Future

Carsten Owerdieck, Americas GE Water & Process Technologies
with Jeff Penny, Jeff Peeters, Sven Baumgarten, Moreno Di Pofi, and Gabor Kicsi
Figure 15: MBR Energy Usage in kWh/MG as a function of flow from Fowler, Dundee, Pooler, Varsseveld, Delphos, Cauley Creek, Healdsburg, LOTT and Bonita Springs. S = Siemens, Z = Zenon, K = Kubota
Membrane BioReactors
Ovivo Report – 2012

Figure 1. Energy Bills
From 13 Full-Scale WWTPs

Dennis Livingston, Ovivo
Figure 15: MBR Energy Usage in kWh/MG as a function of flow from Fowler, Dundee, Pooler, Varsseveld, Delphos, Cauley Creek, Healdsburg, LOTT and Bonita Springs. S = Siemens, Z = Zenon, K = Kubota
# Port Hadlock – Phased Capacity

<table>
<thead>
<tr>
<th></th>
<th>Startup</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
<td>0</td>
<td>6</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td><strong>Annual Ave flow mgd</strong></td>
<td>0.06</td>
<td>0.18</td>
<td>0.36</td>
<td>0.73</td>
</tr>
<tr>
<td><strong>Max Month flow</strong></td>
<td>0.08</td>
<td>0.25</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Peak Hour Flow</strong></td>
<td>0.11</td>
<td>0.68</td>
<td>1.35</td>
<td>2.70</td>
</tr>
<tr>
<td><strong>Treatment Trains – on line</strong></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Treatment Trains – standby</strong></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Emergency storage</strong></td>
<td>none</td>
<td>none</td>
<td>3 days</td>
<td>3 days</td>
</tr>
</tbody>
</table>
Port Hadlock - Energy Estimates

- **Sludge Loading Pumps**
- **Plant Water**
- **Influent Pump Station**
- **Headworks (inc. odor control)**
- **Membrane Thickening**
- **Misc. (Exterior lighting, controls, transformers)**
- **Interior Lighting and HVAC**
- **Disinfection**
- **MBR**

$kWh/MG$ vs. Plant Flow (mgd)

- 0.05 mgd: 7080 kWh/MG
- 0.1 mgd: 1689 kWh/MG
- 0.18 mgd: 3552 kWh/MG
- 0.25 mgd: 2401 kWh/MG
- 0.36 mgd: 2058 kWh/MG
- 0.5 mgd: 1691 kWh/MG
Figure 15: MBR Energy Usage in kWh/MG as a function of flow from Fowler, Dundee, Pooler, Varsseveld, Delphos, Cauley Creek, Healdsburg, LOTT and Bonita Springs. S = Siemens, Z = Zenon, K = Kubota.
## Port Hadlock – MBR Equipment Operation for Energy Estimates

<table>
<thead>
<tr>
<th>Duty Train: (Standby train off)</th>
<th>20% 0.05 mgd</th>
<th>40% 0.1 mgd</th>
<th>72% 0.18 mgd</th>
<th>100% 0.25 mgd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Forward Pumps</td>
<td>Min speed</td>
<td>Flow Paced</td>
<td>Flow Paced</td>
<td>Flow Paced</td>
</tr>
<tr>
<td>Pre &amp; Post anoxic mixers</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Pre-aeration mixer</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Pre-aeration blower</td>
<td>Off</td>
<td>DO paced</td>
<td>DO paced</td>
<td>DO paced</td>
</tr>
<tr>
<td>Membrane blower</td>
<td>Min speed</td>
<td>Variable speed</td>
<td>Variable speed</td>
<td>Variable speed</td>
</tr>
<tr>
<td>Permeate pumps</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>
Port Hadlock - MBR Process Energy Estimates

1 train → 2 trains

- MBR Blower (kWh/MG)
- Pre-Aeration Blower (kWh/MG)
- Permeate Pump (kWh/MG)
- Feed Forward / Traditional Recycle Pump (kWh/MG)
- Post Anoxic Mixer (kWh/MG)
- Pre-Aeration Mixer (kWh/MG)
- Pre-Anoxic Mixer (kWh/MG)
Port Hadlock - UV Disinfection

- Enclosed vessel, low pressure, high output, ~50% turndown
- 30% Design-Two 0.6 mgd reactors (1 duty & 1 standby), add one 0.6 unit in future
- Alternate Design-Two 0.3 mgd reactors (1 duty & 1 standby), add two 0.6 units & flow equalization in future
- 0.3 mgd units save $2,500 power in first year, Less than $40,000 in 20 years; Equipment costs ~ $40k more
- Analyze further in 60% design
Port Hadlock - Power Monitoring

- Power data from
  - MCC’s
  - LCP’s
  - VFD’s
- SCADA displays for operator
Port Hadlock – Other Energy Uses

- Odor Control
  - Only at Headworks
  - Variable speed fan
  - Activated carbon

- HVAC
  - Conventional heat pump
  - Effluent heat pump not cost effective

- Lighting
  - Natural
  - LED
Port Hadlock – Other Energy Uses

• Influent Pumps
  • Constant speed, low velocity in large force main
  • Equalize peak flows in pre-anoxic cell

• Membrane Thickener
  • Batch operation
  • Scour aeration during permeate pumping
  • Cyclic aeration for mixing, aeration, denitrification

• C3 pumps
  • Cyclic operation with hydropneumatic tank
  • Native landscaping minimizes irrigation
Conclusions

- Best MBRs use energy similar to CAS
- Local WA MBRs use more energy
- Turndown is major issue
- Need efficient standby mode
- Need power meters and SCADA tools
- Odor Control uses significant energy at covered plants
- Port Hadlock MBR energy use is promising, at flows above 20% train capacity.
- Port Hadlock needs better turn down for startup & diurnal low flows
  - VFDs for mixers?
  - Defer some membranes?
  - Smaller UV reactors?
  - Smaller treatment trains?
  - Smaller blowers?
## Ovivo Report-2012

<table>
<thead>
<tr>
<th>Location</th>
<th>Type/Design Flow</th>
<th>Average Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant 1</td>
<td>WA HF (0.48 MGD)</td>
<td>0.11 - 23%</td>
</tr>
<tr>
<td>Plant 2</td>
<td>WA HF (1.54 MGD)</td>
<td>0.47 - 31%</td>
</tr>
<tr>
<td>Plant 3</td>
<td>Cauley Creek, GA HF (5.0 MGD)</td>
<td></td>
</tr>
<tr>
<td>Plant 4</td>
<td>Fowler, GA HF (2.5 MGD)</td>
<td></td>
</tr>
<tr>
<td>Plant 5</td>
<td>Santa Paula, CA HF (4.0 MGD)</td>
<td></td>
</tr>
<tr>
<td>Plant 6</td>
<td>WA Ovivo (0.40 MGD)</td>
<td>0.23 - 58%</td>
</tr>
<tr>
<td>Plant 7</td>
<td>WA Ovivo (0.36 MGD)</td>
<td>0.09 - 25%</td>
</tr>
<tr>
<td>Plant 8</td>
<td>WA Ovivo (0.69 MGD)</td>
<td>0.30 - 43%</td>
</tr>
<tr>
<td>Plant 9</td>
<td>WA Ovivo (2.67 MGD)</td>
<td></td>
</tr>
<tr>
<td>Plant 10</td>
<td>Delphos, OH Ovivo (6.0 MGD)</td>
<td></td>
</tr>
<tr>
<td>Plant 11</td>
<td>Dundee, MI Ovivo (1.5 MGD)</td>
<td></td>
</tr>
<tr>
<td>Plant 12</td>
<td>Sanpou, JP KUBOTA (16 MGD)</td>
<td></td>
</tr>
<tr>
<td>Plant 13</td>
<td>Moriyama, JP KUBOTA (1.3 MGD)</td>
<td></td>
</tr>
</tbody>
</table>
Baseline Energy Analysis - Informs Port Hadlock Design

- Rough Baseline for MBR energy use
- Energy Monitoring - Need power meters and SCADA tools
- MBR - turndown is critical, especially for small plants
- MBR – need efficient standby mode for membranes
- Odor control - surprisingly large energy use
- UV disinfection – turndown & overheating
Port Hadlock - UV Disinfection

Enclosed Vessel – low pressure, high output, ~50% turndown

Current Design
• Two 0.6 mgd reactors in parallel (1 duty & 1 SB).
• 12 years later - Three 0.6 mgd reactors in parallel (2 duty & 1 SB).
• Equipment Cost: $345,000

Alternate Design
• Two 0.3 mgd reactors in parallel (1 duty & 1 SB)
• 3 years later, add two 0.6 mgd reactors in series to each train (1 Duty & 1 SB).
• Equipment Cost: $380,000