BIOLOGICAL FILTRATION FOR GROUNDWATER TREATMENT

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American Water Works Association
New York Section
New York’s Water Event
Saratoga Springs, New York
April 15, 2015
PRESENTATION OVERVIEW

1. Project Background
2. Water Quality Challenges
3. Alternatives Considered
4. Biological Filtration Explained
5. The Pilot Program
6. Conclusions
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The Existing Water Treatment Plant

- Conventional treatment
- Operator familiarity
- Regulatory compliant
- High customer satisfaction
- Age and efficiency issues
- Facility plan was completed to evaluate options for WTP
WTP Facility Plan Report

- Initiated to address issues with:
  - operator safety
  - inadequate access
  - insufficient operational reliability and redundancy
  - hydraulic limitations
- Life cycle analysis costs for upgrade vs. new plant nearly equal
- City subsequently selected 2-step Design-Build Procurement process
Design-Build Solicitation and Selection

- RFQ solicited SOQ’s, 3 design/build entities short-listed
- RFP included request for base and alternate design proposals
- Agreement with CDM Smith/Haskell executed in March 2013
A Focus on Life Cycle Costs

- Used LCC Analysis in Facility Plan and County/City WTP feasibility study
- D/B RFP required LCC proposals to include:
  - LCC for base & alternate
  - Approach to minimize LCC
- LCC Proposals weighted 30 out of 100 points
Base and Alternative Bids Achieve LEED Certification and DWSRF Funding

- **LEED Certification:**
  - Consolidated facilities = entire superstructure LEED Certification
  - No deforestation
  - Rain gardens provide storm water mitigation
- **DWSRF Funding:**
  - Green components, including LEED Certification, qualify City for Green Loan and Grant Funding
Design Approach that Maximizes Green Funding Opportunities

- Consolidated facility vs. campus
- Sustainable design and construction principles

<table>
<thead>
<tr>
<th>Project Component</th>
<th>Eligible GPR Funding Amount ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEED Certification of Treatment Plant Building</td>
<td>$3.5 – $4.0</td>
</tr>
<tr>
<td>Energy Efficient Equipment</td>
<td>$1.2 - $1.4</td>
</tr>
<tr>
<td>Residuals Disposal and Recycle Systems</td>
<td>$2.0 – $2.4</td>
</tr>
<tr>
<td>SCADA System</td>
<td>$0.4 - $0.6</td>
</tr>
<tr>
<td>Demolition Material Recycling</td>
<td>$0.6 - $1.0</td>
</tr>
<tr>
<td>Biofiltration System (alternative design only)</td>
<td>$3.2 - $3.6</td>
</tr>
</tbody>
</table>
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## Sustainable Raw Water Quality

- Low organic content
- Significant iron – Moderate manganese – hydrogen sulfide
- Free chlorine usage – no issues

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Alkalinity (mg/L as CaCO₃)</th>
<th>Total Hardness (mg/L as CaCO₃)</th>
<th>Turbidity (NTU)</th>
<th>Iron (mg/L)</th>
<th>pH (SU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>22</td>
<td>20</td>
<td>3.6</td>
<td>8.3</td>
<td>5.8</td>
</tr>
<tr>
<td>Maximum</td>
<td>38</td>
<td>44</td>
<td>13</td>
<td>14</td>
<td>7.1</td>
</tr>
<tr>
<td>Minimum</td>
<td>5.4</td>
<td>7.3</td>
<td>0.2</td>
<td>2.4</td>
<td>4.9</td>
</tr>
</tbody>
</table>
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### Oxidation/Filtration is Time-Tested – Excellent Equipment Combinations

<table>
<thead>
<tr>
<th>Oxidants</th>
<th>Clarification</th>
<th>Filtration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (from air)</td>
<td>Conventional with Plate Settlers</td>
<td>Multimedia Gravity Filters</td>
</tr>
<tr>
<td>Ozone</td>
<td>Dissolved Air Flotation</td>
<td>Mono-medium Deep Bed Gravity Filters</td>
</tr>
<tr>
<td>Free Chlorine</td>
<td>Superpulsators</td>
<td>Mono-Medium Pressure Filtration</td>
</tr>
<tr>
<td>Chlorine Dioxide</td>
<td>Actiflo Ballasted Sedimentation</td>
<td>Pressure Ultrafiltration/Microfiltration</td>
</tr>
<tr>
<td>Permanganate</td>
<td>Adsorption Clarification</td>
<td>Submerged (Vacuum) Ultrafiltration</td>
</tr>
</tbody>
</table>
Base Design Aeration with Conventional Filtration will Provide Effective Treatment

- Plays to the operating staffs’ strengths and knowledge
- Regulatory-compliant
- Expeditious design and construction path
# Fe/Mn Removal Technologies

<table>
<thead>
<tr>
<th>Basic Technology</th>
<th>Treatment Alternative</th>
<th>Industry Experience with Similar Water Quality</th>
<th>Manufacturer Availability</th>
<th>Capital Cost</th>
<th>Operating Cost</th>
<th>Life Cycle Cost</th>
<th>Operability</th>
<th>Treatment Effectiveness</th>
<th>Piloting Required?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media Filtration</td>
<td>Conventional Treatment</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Low/Medium</td>
<td>Good</td>
<td>Good</td>
<td>No</td>
<td>Staff familiarity is high. Existing facility operating well for 70+ years. Long detention time allowing longer time for operator response.</td>
</tr>
<tr>
<td>Media Filtration</td>
<td>Package Systems (Adsorption Clarification &amp; Gravity filter vessels, Superpolys, DAF, Activated)</td>
<td>Low to medium</td>
<td>High</td>
<td>Low to Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Fair</td>
<td>Fair</td>
<td>Yes</td>
<td>High life cycle cost due to requirement to replace vessels during 50 year life cycle. Good staff familiarity. Generally, highly reliable, but high iron loading causes concern. Limited operation detention time requiring quick operator response.</td>
</tr>
<tr>
<td>Media Filtration</td>
<td>Pressurized Clarification &amp; Filtration</td>
<td>None</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Fair</td>
<td>Fair</td>
<td>Yes</td>
<td>High life cycle cost due to requirement to replace vessels during 50 year life cycle. Treatment train fully enclosed. Pump through application. Limited operation detention time requiring quick operator response.</td>
</tr>
<tr>
<td>Media Filtration</td>
<td>Pressure Filters/Direct Filtration</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Fair</td>
<td>Fair</td>
<td>Yes</td>
<td>May have high backwash demands. Low water efficiency. Vessel replacement necessary after 20+ years. High iron loading causes concern. Pump through application. Limited operation detention time requiring quick operator response.</td>
</tr>
<tr>
<td>Membrane Filtration</td>
<td>Submerged Membranes</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Good</td>
<td>Yes</td>
<td>Complex system for operations. Membrane replacement may be required at 10 years. Water quality will be good out of membranes during upset event, but could require membrane replacement after upset event.</td>
</tr>
<tr>
<td>Membrane Filtration</td>
<td>Pressure Membranes</td>
<td>Low to medium</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Poor</td>
<td>Good</td>
<td>Yes</td>
<td>Complex system for operations. Membrane replacement may be required at 10 years. Limited operation detention time with short operator response time during plant upset event. Water quality will be good out of membranes, but could require membrane replacement after upset event.</td>
</tr>
<tr>
<td>Membrane Filtration</td>
<td>Ion Exchange</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Fair</td>
<td>Fair</td>
<td>Yes</td>
<td>High iron content would overwhelm ion exchange media; number of units required to overcome this effort is not viable.</td>
</tr>
<tr>
<td>Membrane Filtration</td>
<td>Biofiltration</td>
<td>Medium</td>
<td>Limited</td>
<td>Low</td>
<td>Lowest</td>
<td>Lowest</td>
<td>Good</td>
<td>Good</td>
<td>Yes</td>
<td>Simple system for operations. More limited installation resume than other technologies. Potential savings in capital and O&amp;M. Some forgiveness during process upset allowing longer operator response time.</td>
</tr>
</tbody>
</table>
Biofiltration Has the Potential for Millions in Life Cycle Cost Savings

- Eliminates coagulant and pre-oxidation chemicals
- Relatively higher filtration rates decreases space requirements
- Longer filter runs
- Denser floc
- Pilot testing necessary
1. Project Background
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4. **Biological Filtration Explained**
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The Technology
What is Biologically Active Filtration (BAF)?

- BAF in drinking water treatment is the controlled growth and management of beneficial bacteria in granular media filters to meet a variety of water quality goals.
### BAF Enhances Water Quality and Reduces Treatment Costs Using Good Bacteria

<table>
<thead>
<tr>
<th>Water Quality Enhancements:</th>
<th>Economic Benefits:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• TOC and DBP precursors</td>
<td>• Lower ozone doses for T&amp;O</td>
</tr>
<tr>
<td>• Oxidation by products</td>
<td>• Lower coagulant doses for TOC removal and DBP control</td>
</tr>
<tr>
<td>• Biological stability</td>
<td>• Extend GAC bed life</td>
</tr>
<tr>
<td>• Taste and odor</td>
<td>• Reduce demand for residual disinfectants</td>
</tr>
<tr>
<td>• <strong>Iron and manganese</strong></td>
<td>• May remove NDMA for lower cost than UV-AOP</td>
</tr>
<tr>
<td>• Endocrine disrupters</td>
<td>• Decrease membrane fouling</td>
</tr>
<tr>
<td>• Pharmaceuticals and personal care products</td>
<td></td>
</tr>
<tr>
<td>• Perchlorate, nitrate, nitrite, hexavalent chromium and uranium</td>
<td></td>
</tr>
</tbody>
</table>
BAF Occurs in Any Granular Media Filter Where Beneficial Bacteria are Allowed to Proliferate.
Slow Sand Filtration (SSF) is the Oldest, and Least Complicated Engineered BAF Process

- Good turbidity and particulate removal
- No chemicals or waste streams (other than sand)
- Reduces TOC by 20-30%
- Add ozone for TOC removal >50%
- Excellent pretreatment for membranes with SDI <3
Bacteria Will Acclimate to Food Sources When Residual Disinfectants are Absent or Removed

**Conventional Treatment Process**

- $\text{Cl}_2$
- $\text{NH}_2\text{Cl}$
- $\text{ClO}_2$

**Aerobic Biological Treatment**

- None or any oxidant

**Anoxic Biological Treatment**

- Electron Donor

Electron Donor Options:
- Anth
- Sand
- GAC
Design Guidelines for Biological Filters

- There are no industry-standard guidelines for designing biological filters.
- Ten States Standards contains minimal recommendations for design of biological filters.
- Ten States Standards states that biological filters may be considered based on pilot studies pre-approved by the reviewing authority.
Biofiltration for Fe and Mn Removal – Natural Alternative Minimizing Chemical Usage

- Catalytic oxidation using natural bacteria
- Synthetic reusable media
- Air and minimal chemical usage
- Limited number of established suppliers for package systems
Biofiltration for Fe and Mn Removal – Natural Alternative Minimizing Chemical Usage

Biotic Water Stability Diagram for Fe and Mn

- MnO₂
- Mn²⁺
- Mn₃O₄
- Fe²⁺
- Fe(OH)₃

pH

EH (mV)
Other Water Suppliers Using Biological Filtration for Iron and Manganese

- Simplicity
- Dissolved Oxygen – Typically there is more concern about “white water” than high effluent Fe or Mn!

$ Minimal operator attention required for process stability

$ No coagulant

$ Backwash frequency
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## Raw Water Quality

<table>
<thead>
<tr>
<th>Well</th>
<th>Avg. Fe (mg/l)</th>
<th>Avg. Mn (mg/l)</th>
<th>pH</th>
<th>Capacity (gpm)</th>
<th>Aquifer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>6.1</td>
<td>0.10</td>
<td>6.1</td>
<td>620</td>
<td>Magothy</td>
</tr>
<tr>
<td>5</td>
<td>6.2</td>
<td>0.10</td>
<td>6.2</td>
<td>950</td>
<td>Magothy</td>
</tr>
<tr>
<td>6</td>
<td>4.7</td>
<td>0.08</td>
<td>5.8</td>
<td>900</td>
<td>Magothy</td>
</tr>
<tr>
<td>7</td>
<td>7.3</td>
<td>0.14</td>
<td>7.1</td>
<td>1,000</td>
<td>Magothy</td>
</tr>
<tr>
<td>10</td>
<td>3.1</td>
<td>0.07</td>
<td>4.9</td>
<td>1,200</td>
<td>Upper Patapsco</td>
</tr>
<tr>
<td>11</td>
<td>3.9</td>
<td>0.10</td>
<td>5.4</td>
<td>1,150</td>
<td>Upper Patapsco</td>
</tr>
<tr>
<td>12</td>
<td>13.1</td>
<td>0.56</td>
<td>6.6</td>
<td>2,000</td>
<td>Lower Patapsco</td>
</tr>
<tr>
<td>14</td>
<td>12.1</td>
<td>0.64</td>
<td>6.7</td>
<td>2,000</td>
<td>Lower Patapsco</td>
</tr>
</tbody>
</table>
Pilot Testing - Some Notes

- Goals relative to Secondary MCL’s
  - Better than SMCL 0.30 mg Fe/L
  - Better than SMCL 0.05 mg Mn/L

- Loading Rates from 3 to 9 gpm/sf

- No “seeding”!

- High iron + too much applied air = ?
The Pilot Testing Protocol

- Well from Lower Patapsco Aquifer
- Well from Magothy Aquifer
- Well from Upper Patapsco Aquifer
- Long Term Composite Test (37 days)
- Stress Tests
  - Turn off air
  - Turn off pH adjustment
  - Introduce appreciable chlorine (simulate an accident)
  - Introduce chlorinated backwash
  - Three day shut down test (e.g. Hurricane Sandy)
Major Findings I

- Composite Testing Filtered Water:
  - Average Effluent Iron 0.012 mg/L
  - Average Effluent Manganese 0.0052 mg/L

- Loading Rates:
  - Ferazur 5 to 7 gpm/sf
  - Mangazur up to 7 gpm/sf

- Filter Run Times:
  - Ferazur > 24 hours
  - Mangazur > 200 hours
Major Findings II

• Ferazur Conditions:
  – Dissolved Oxygen in 1.6 mg/L, out 0.9 mg/L
  – Alkalinity boost was needed for Well 10 when tested by itself
• Mangazur Conditions:
  – Dissolved Oxygen boosted upward
  – pH boosted to 9.4 (matched City’s finished water pH)
• Acclimation 7 to 14 days for iron bacteria
• Acclimation 14 to 28 days for manganese bacteria
• Quick recovery after aeration loss and dormancy
Alternative Design
Simplified Diagram

Well House
(Typ. Of 8)

Air  pH Adjust  Soda Ash or Sodium Bicarbonate

10 Ferazur Vessels @ 5.4 gpm/sf

Air  pH Adjust

8 Mangazur Vessels @ 6.7 gpm/sf

NaOCl  Lime  Fluoride
City of Annapolis
DESIGN/BUILD OF A NEW WATER TREATMENT PLANT
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Conclusions

1. Biological filtration was very effective on very high iron / moderate manganese source water
2. Alkalinity in source water not to be overlooked!
3. Use of lime in conventional plant versus liquid NaOH or liquid KOH in biological plant benefited conventional plant in the life cycle cost analysis
4. Biological Filtration is a worthy consideration for future similar applications
New Conventional Plant Designed
THANK YOU TO...

City of Annapolis

Infilco Degremont, Inc.

Blueleaf, Inc.

Maryland Department of the Environment