Evaluating Operational Factors that Influence Biofiltration Performance in Various Source Waters

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Mike Hughes – City of Raleigh
Agenda

01 Biofiltration and WRF Project Overview
02 Upstream Oxidant Addition
03 Microbial Activity Enhancement
04 Upstream Process Modifications
01 Biofiltration & WRF Project Overview
What is Biofiltration?

**Conventional Filtration**
- Disinfectant
- Flow

**Biofiltration**
- Flow

**Capabilities:**
- Absorption/adsorption (GAC)
- Solids removal
- Low operating costs

**Capabilities:**
- Decreased re-growth potential
- Reduced corrosion potential
- Reduced taste and odor
- Reduced DBPs
- Improved residual
Microorganism health is important for filter productivity

Stressed microorganisms produce extracellular polymeric substances (EPS)

EPS accumulates within the biofilter media

Accumulation leads to increased head loss and shorter filter run times

Source: WRF 4215
WRF #4555 Objectives

1. Identify biofilter optimization strategies that can increase contaminant removal and/or improve hydraulics
2. Develop a guidance for utilities on when and how to implement strategies
16 diverse utilities participated in the WRF project

Regional Participants
City of Raleigh
Greenville Utilities Commission
Newport News Waterworks

Participating Utilities
- Arlington Water Utilities
- Halifax Water
- Southern Nevada Water Authority
- City of Raleigh
- Newport News
- City of Tampa
- City of Tulsa
- Toronto Water Treatment and Supply
- Fairfax Water Authority
- Halton Region Public Works
- Gwinnett County
- Trinity River Authority
- Denver Water
- Aurora Water
- El Paso Water Utilities
- Greenville Utilities Commission
WRF 4555 - Optimization Strategies

Influent Trough
Dual Media Filter
Underdrains
Backwash pumps
**#1 - Upstream Processes**

- Raw Water
- Coagulation/Flocculation
- Sedimentation
- Settled Water

### WRF 4555 - Optimization Strategies

- Influent Trough
- Dual Media Filter
- Underdrains
- Backwash pumps
WRF 4555 - Optimization Strategies

1. Upstream Processes
   - Raw Water
   - Coagulation/Flocculation
   - Sedimentation

2. Pre-Ozonation
   - #1 - Pre-Oxidants: Cl₂, H₂O₂, MnO₄⁻, NH₄Cl₂
   - #2 - Ozone Generator
   - Ozone Contact
   - Influent Trough
   - Dual Media Filter
   - Underdrains
   - Backwash pumps

Settled Water

Settled Water
#1 - Upstream Processes
Raw Water → Coagulation/Flocculation → Sedimentation

Settled Water → Ozone Contactor

#2 - Pre-Oxidation
Ozone Generator

#2 - Pre-Ozonation

Backwash pumps

Influent Trough
Dual Media Filter
Underdrains

#3 - Enhancing Microbial Activity

Cl₂, H₂O₂, MnO₄⁻, NH₄Cl₂

WRF 4555 - Optimization Strategies
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WRF 4555 - Optimization Strategies

#1 - Upstream Processes
Raw Water → Coagulation/Flocculation → Sedimentation → Ozone Generator → Ozone Contactor → #2 - Pre-Oxidation

Settled Water → Backwash pumps + Air Scour → Underdrains → Dual Media Filter → Influent Trough

#2 - Pre-Oxidation: \( \text{Cl}_2, \text{H}_2\text{O}_2, \text{MnO}_4^-, \text{NH}_4\text{Cl}_2 \)

#3 - Enhancing Microbial Activity

#4 - Filter Backwashing Procedure

#5 - Filter Media Type
Three strategies will be discussed today

<table>
<thead>
<tr>
<th>Utility</th>
<th>Pilot or Full-Scale</th>
<th>Upstream Oxidant Addition</th>
<th>Microbial Activity Enhancement</th>
<th>Upstream Process Modifications</th>
<th>Backwash</th>
<th>Media Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington Water Utilities</td>
<td>Pilot/Full</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gwinnett County Dept. of Water Res.</td>
<td>Pilot/Full</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Halifax Water</td>
<td>Pilot</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>City of Tampa</td>
<td>Pilot</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Southern Nevada Water Authority</td>
<td>Pilot/Full</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>Toronto Water</td>
<td>Pilot</td>
<td>✓</td>
<td></td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Denver Water</td>
<td>Full</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fairfax County Water Authority</td>
<td>Full</td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td>City of Raleigh</td>
<td>Full</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newport News Water Works</td>
<td>Full</td>
<td>✓</td>
<td></td>
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</tbody>
</table>
Five metrics were used to evaluate optimization strategies

- Improvements in organics removal
- Improvements in inorganics removal
- Increases in filter run hours
- Decreases in head loss and/or head loss accumulation rate
- Decrease in filter effluent turbidity
Changes in source water quality were considered

- At least one year of analytical and operational data
- Synergy evaluations were conducted to determine how one optimization strategy might affect another
- Data were normalized to account for source water changes

If normalized value = 1, test filter = control filter
02 Results – Upstream Oxidant Addition
How can upstream oxidants improve biofilter performance?

Upstream oxidants added

Nondegradable organic carbon becomes more easily degradable

More removal using microorganisms is achievable

Notes:
SNWA BAF Pilot System
Water Source: Colorado River Water
DOC: -2.5 mg/L
pH: ~8.0 STU
### Five upstream oxidants were evaluated

<table>
<thead>
<tr>
<th>Utility</th>
<th>Pilot or Full-Scale</th>
<th>Ozone Dose (mg/L)</th>
<th>Chloramine Dose (mg/L)</th>
<th>Permanganate Dose (mg/L)</th>
<th>Chlorine Dose (mg/L)</th>
<th>Peroxide Dose (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halifax</td>
<td>Pilot</td>
<td>—</td>
<td>—</td>
<td>0.15–0.8</td>
<td>0.2–0.3</td>
<td>0.5–1</td>
</tr>
<tr>
<td>Toronto</td>
<td>Pilot</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.3</td>
</tr>
<tr>
<td>Gwinnett</td>
<td>Pilot</td>
<td>0.25–1.7</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.25–1.25</td>
</tr>
<tr>
<td>City of Tampa</td>
<td>Pilot</td>
<td>1.3–5.1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SNWA</td>
<td>Pilot</td>
<td>0–14</td>
<td>—</td>
<td>—</td>
<td>0.5–2.0</td>
<td>2.0–5.0</td>
</tr>
<tr>
<td>Arlington</td>
<td>Pilot/Full</td>
<td>0.5–2.4</td>
<td>0.5–1.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Raleigh</td>
<td>Full</td>
<td>3.5–4.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Newport News</td>
<td>Full</td>
<td>0.9–3.9</td>
<td>—</td>
<td>—</td>
<td>0.25–2.0</td>
<td>—</td>
</tr>
<tr>
<td>Fairfax Water</td>
<td>Full</td>
<td>1.1–1.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.5–1.5</td>
</tr>
<tr>
<td>Overall Range</td>
<td>Tested</td>
<td>—</td>
<td>0.25–14</td>
<td>0.15–0.8</td>
<td>0.2–2.0</td>
<td>0.25–5.0</td>
</tr>
</tbody>
</table>
Ozone provides hydraulic improvement and turbidity removal

**Ozone Addition**

- Increased filter run time
- Decreased effluent turbidity
Chloramine addition significantly decreased headloss
Chlorine addition increases filter run time.
Results – Microbial Activity Enhancement
Upstream nutrients promote healthy microorganisms

<table>
<thead>
<tr>
<th></th>
<th>Carbon</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 M</td>
<td>10 M</td>
<td>1 M</td>
<td></td>
</tr>
<tr>
<td>1 mg/L</td>
<td>0.1 mg/L</td>
<td>0.03 mg/L</td>
<td></td>
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</table>

Stressed Biomass (Nutrient-Limited)

Healthy Biomass (Nutrient-Enhanced)

*ESEM performed by USEPA ORD
Phosphorus was the most commonly studied nutrient

<table>
<thead>
<tr>
<th>Utility</th>
<th>Pilot or Full-Scale</th>
<th>Phosphorus</th>
<th>Ammonia</th>
<th>Phosphorus + Ammonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington</td>
<td>Pilot/Full</td>
<td>0.025 mg/L-P</td>
<td>0.5, 1.0, 1.5 mg/L-N</td>
<td>0.5 mg/L-N + 0.025 mg/L-P 1.5 mg/L-N + 0.025 mg/L-P</td>
</tr>
<tr>
<td>Gwinnett County</td>
<td>Pilot</td>
<td>0.1 mg/L-P with and</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>without pH adjustment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raleigh</td>
<td>Full</td>
<td>0.1 mg/L, 0.2 mg/L,</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4 mg/L phosphoric</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>acid with and without pH adjustment</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Fairfax Water</td>
<td>Pilot</td>
<td>0.5–0.10 mg/L-P</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
Ammonia and phosphorus decreased headloss

- 0.5 mg/L of Ammonia - 0.025 mg/L phosphorus
- 1.5 mg/L of Ammonia
- 1.5 mg/L of Ammonia - 0.025 mg/L phosphorus
Phosphorus addition decreased headloss & increased filter run time.
04 Results – Upstream Process Modifications
Utilities studied the addition of various chemicals

<table>
<thead>
<tr>
<th>Utility</th>
<th>Pilot or Full-Scale</th>
<th>Chemical &amp; Dose (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halifax</td>
<td>Pilot</td>
<td>Aluminum Sulfate (8 – 12 mg/L)</td>
</tr>
<tr>
<td>Arlington</td>
<td>Pilot</td>
<td>Aluminum Sulfate (16 – 48 mg/L)</td>
</tr>
<tr>
<td>Raleigh</td>
<td>Full</td>
<td>PAC (2 &amp; 3 mg/L)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Caustic (Increased 1-2 pH units)</td>
</tr>
<tr>
<td>City of Tampa</td>
<td>Pilot</td>
<td>Filter Aid (0 – 0.09 mg/L)</td>
</tr>
</tbody>
</table>
Caustic increased filter run time in biofilters

Normalized Filter Run Time (Hours)

Before Caustic Addition

After Caustic Addition

Test Filter 1

Test Filter 2
Ozone & caustic increased filter run time in downstream filters
Biofiltration can reduce upstream alum dose
05 Conclusions
Biofiltration can provide various benefits for different utilities

- **Oxidant Addition**
  - Low doses of ozone and chlorine can be beneficial for three purposes:
    - Reduction of EPS
    - More biodegradable organics
    - Particle stability

- **Nutrient Addition**
  - Site-specific benefits of adding phosphorus, but the concentration must be optimized for controlling hydraulics

- **Upstream Process Modifications**
  - Adding caustic/ozone increased filter run time in downstream filters
  - Minimal impact of varying alum dose on biofilter performance
Questions?

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