BALANCING COSTS AND BENEFITS OF POTABLE REUSE TREATMENT TECHNOLOGIES

Session B-2: Potable Reuse: Treatment, Trends, and Guidelines
July 12th, 2013
3:00pm – 3:30pm
Austin, Texas

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Overview

• Introduction
• Treatment Processes
• Evaluation Approach
• Results
• Summary and Conclusions
INTRODUCTION

Balancing Costs and Benefits of Potable Reuse Treatment Technologies
Introduction

• Lingering drought & increasing water supply needs in Texas
• Water supply options being considered & implemented include potable water reuse
• Many common potable reuse treatment approaches are costly to build & operate
• This presentation compares two potable reuse treatment approaches
TREATMENT PROCESSES

Balancing Costs and Benefits of Potable Reuse Treatment Technologies
Common Potable Reuse Treatment Processes

• Reverse osmosis (RO) based treatment
  – More common in Western US and internationally

• Granular activated carbon (GAC) based treatment
  – More common in Eastern US

• Multiple barriers to
  – Bulk organic matter
  – Trace organics
  – Pathogens
Treatment Train 1 – RO Based Treatment

- Disposal of RO concentrate required

Ex. 18.5 mgd RO-based Plant
Treatment Train 2 – GAC Based Treatment

[Diagram showing treatment process]

Ex. 54 mgd GAC-based Plant
## Train 1 - Design Criteria (Truncated)

### Table 1 - Design Criteria for RO-Based Approach

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average FeCl₃ Dose</td>
<td>40 mg/L</td>
</tr>
<tr>
<td>Rapid Mix G</td>
<td>1000 s⁻¹</td>
</tr>
<tr>
<td>Flocculation Time</td>
<td>20-minutes</td>
</tr>
<tr>
<td>Clarifier Loading Rate</td>
<td>0.8 m/hr (0.32 gpm/sf)</td>
</tr>
<tr>
<td>Average Monochloramine Dose</td>
<td>5 mg/L</td>
</tr>
<tr>
<td>MF Design Flux</td>
<td>67 l/mh (40 gfd)</td>
</tr>
<tr>
<td>Average Transmembrane Pressure</td>
<td>110 kPa (16 psi)</td>
</tr>
<tr>
<td>MF Mini-clean Frequency</td>
<td>Once every 3 days</td>
</tr>
<tr>
<td>MF CIP Frequency</td>
<td>Once per year</td>
</tr>
<tr>
<td>RO Design Flux</td>
<td>19 l/mh (10.6 gfd)</td>
</tr>
<tr>
<td>RO Feed Pressure</td>
<td>150 m (213 psi)</td>
</tr>
<tr>
<td>RO Recovery</td>
<td>85%</td>
</tr>
</tbody>
</table>
## Train 2 - Design Criteria (Truncated)

### Table 2 - Design Criteria for GAC-Based Approach

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime Dose</td>
<td>140 mg/L</td>
</tr>
<tr>
<td>Lime type</td>
<td>Hydrated Lime</td>
</tr>
<tr>
<td>Lime Clarification Type</td>
<td>Solids Contact Clarifier</td>
</tr>
<tr>
<td>Clarifier Loading Rate</td>
<td>14.6 m/hr (6 gpm/sf)</td>
</tr>
<tr>
<td>CO2 Recarbonation Dose</td>
<td>18 mg/L</td>
</tr>
<tr>
<td>Filter Loading Rate</td>
<td>11.5 m/hr (4.7 gpm/sf)</td>
</tr>
<tr>
<td>Filter Media Depth</td>
<td>3 feet</td>
</tr>
<tr>
<td>GAC Influent PS TDH</td>
<td>25-feet</td>
</tr>
<tr>
<td>GAC Filter Loading Rate</td>
<td>16.1 m/hr (6.6 gpm/sf)</td>
</tr>
<tr>
<td>GAC Media Depth</td>
<td>6.1 m (20 feet)</td>
</tr>
<tr>
<td>GAC Regeneration Frequency</td>
<td>12.5% of media per year</td>
</tr>
</tbody>
</table>
EVALUATION APPROACH

Balancing Costs and Benefits of Potable Reuse Treatment Technologies
Evaluation Approach

• **Financial**
  – Evaluated the capital cost and annual operating cost

• **Environmental**
  – Estimated greenhouse gas emissions

• **Social - Water Quality:**
  – Evaluated removal effectiveness for CECs, bulk organic matter, pathogens, and nutrients
  – TDS for aesthetics
Evaluation Basis

• Treatment train configuration and finished water quality data collected
  – two full-scale GAC-based plants
  – four full-scale RO-based plants

• Actual design criteria & chemical & power consumption data was collected

• Capital costs estimated for 18.5 mgd (70 MLD)
  – Used CH2M HILL’s parametric cost estimating program
  – Eliminates variations caused by construction date & market conditions

• O&M costs determined using actual chemical & power consumption data

• GHG estimates as environmental surrogate
Capital and Operating Cost Comparison

- Plant size = 18.5 mgd; average flow of 11 mgd assumed for annual operating costs
- Capital costs include all liquid and solids treatment
- Capital costs are for a complete and fully-operational plant, includes site development, electrical, computer, etc.
- Annual O&M costs include power, consumables, and regular replacement for items with an expected life of less than 20-years (e.g., membranes).
- Labor costs were specifically not included to avoid errors introduced when using percentages for these values.
- Power costs based on $0.056/kwh.
RESULTS

Balancing Costs and Benefits of Potable Reuse Treatment Technologies
Capital Cost Comparison

<table>
<thead>
<tr>
<th>RO-Based</th>
<th>GAC-Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO</td>
<td>GAC</td>
</tr>
<tr>
<td>MF</td>
<td>Filters</td>
</tr>
<tr>
<td>UV AOP</td>
<td>Lime Clarifier</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Chemicals</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>Centrifuge</td>
</tr>
<tr>
<td>Lamella Clarifier</td>
<td>Lamella Clarifier</td>
</tr>
<tr>
<td>Gravity Thickener</td>
<td>Gravity Thickener</td>
</tr>
<tr>
<td>Break Tank</td>
<td>Backwash Supply &amp; Waste</td>
</tr>
</tbody>
</table>

45% Higher

Construction Cost (Millions of US Dollars)

Capital Cost Comparison
Annual O&M Cost Comparison

Top four bars represent O&M costs for GAC pump station, lime clarification, CO2, and filter backwash handling.

- RO-Based
- GAC-Based
- GAC Regen Freq increased to 1x/yr
Figure 5: Annual O&M Costs for RO System

- RO-Based
- GAC-Based
- GAC Regen Freq increased to 1x/yr

Annual O&M Costs – RO System

- RO
- MF
- UV AOP
- FeCl3
- Lime
- Hypo
- Centrifuge

Annual O&M Cost (US Dollars)

- $0
- $500,000
- $1,000,000
- $1,500,000
- $2,000,000
- $2,500,000
- $3,000,000
- $3,500,000
- $4,000,000

- $0
- $200,000
- $400,000
- $600,000
- $800,000
- $1,000,000
- $1,200,000
- $1,400,000
- $1,600,000

- Cartridge Filter Replacement
- Antiscalant
- Membrane Replacement
- Pumping

Annual Cost (US Dollars)

- RO
Figure 6: Annual O&M Costs for MF System

- **RO-Based:**
  - Centrifuge
  - Hypo
  - Lime
  - FeCl3
  - UV AOP
  - MF
  - RO

- **GAC-Based:**
  - EFM
  - Membrane Replacement
  - Pumping

GAC Regen Freq increased to 1x/yr
Annual O&M Costs – UVAOP System

Figure 6: Annual O&M Costs for UVAOP System

- **Annual O&M Cost (US Dollars)**
  - $0
  - $500,000
  - $1,000,000
  - $1,500,000
  - $2,000,000
  - $2,500,000
  - $3,000,000
  - $3,500,000
  - $4,000,000

- **RO-Based**
  - Centrifuge
  - Hypo
  - Lime
  - FeCl₃
  - UV AOP
  - MF
  - RO

- **GAC-Based**
  - Lamps, Sleeves, Ballasts
  - H₂O₂
  - Power

- **GAC Regen Freq increased to 1x/yr**
Carbon Footprint (GHGs)

• Equivalent CO2 emissions calculated by:
  – For electricity, used the U.S. average: 1962.5 lbs CO2 / MWh (0.9 kg CO2 / kWh)
  – 0.96 kg CO2/kg GAC regenerated, which is based on a regeneration energy use of 6,000 btu/lb GAC

• Other sustainability impacts not directly accounted for:
  – RO treatment train requires 15% more raw water; impacts users and environmental flows downstream of IPR plant
  – CO2 Sequestration - CO2 from onsite boiler, dryer/pelletizer and GAC furnace are compressed and added to water to neutralize hydroxides
O&M-Related CO₂ Estimates

<table>
<thead>
<tr>
<th></th>
<th>Tons CO₂e / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO-Based</td>
<td></td>
</tr>
<tr>
<td>GAC-Based</td>
<td></td>
</tr>
</tbody>
</table>

- **Chemicals**
- **Power**
Water Quality

• Bulk Water Quality
  – TOC
  – TDS
  – Phosphorus
  – Nitrogen
  – Turbidity
  – Total coliform
  – E. Coli

• Chemicals of Emerging Concern (CECs)
  – Pharmaceutical
  – Personal care products
  – Endocrine disrupting compounds
Total Organic Carbon (TOC)

- **Avg Finished Water TOC**
  - GAC1 = 2.7 mg/L
  - RO3 = 0.6 mg/L

- **Downstream WTP for GAC plant includes GAC and ozone**
  - GAC1 effluent has lower TOC than inflows to reservoir

- **While not needed, more frequent GAC regeneration (e.g., 100%/yr vs. current 12.5%/yr) would yield lower TOC**
Total Dissolved Solids

- **Avg Finished Water TDS**
  - GAC1 = 398 mg/L
  - RO3 = 130 mg/L
- **GAC treated water TDS is higher than RO treated water TDS**
- **TDS for GAC is still well below secondary MCL (500 mg/L)**
Phosphorus, Nitrogen, Coliforms

• **Avg Finished Water Phosphorus**
  – GAC1 = 0.06 mg/L
  – RO3 = 0.02 mg/L

  Both very low levels

• **Avg Finished Water Nitrogen**
  – GAC1 = 12 mg/L*
  – RO3 = 0.6 mg/L

  * Mostly nitrate; intentionally discharged at 12-16 mg/L during reservoir stratification to improve quality

  * At all other times, GAC treated water is at 3-8 mg/L (EPA MCL = 10 mg/L)

• **Coliforms – Not detected**
CECs

- CECs at both RO & GAC-based plants are very low (in most cases BDL)

- Some CECs are present in the finished water at both the RO and GAC-based plants

<table>
<thead>
<tr>
<th>Constituent</th>
<th>GAC-Based Plants</th>
<th>RO-Based Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GAC1</td>
<td>GAC2</td>
</tr>
<tr>
<td>Sulfamethoxazole</td>
<td>4.2</td>
<td>BDL30</td>
</tr>
<tr>
<td>Carbamazepine</td>
<td>53.7</td>
<td></td>
</tr>
<tr>
<td>Gemfibrozil</td>
<td>2.1</td>
<td>BDL10</td>
</tr>
<tr>
<td>Diclofenac</td>
<td>BDL1</td>
<td>BDL10</td>
</tr>
<tr>
<td>Naproxen</td>
<td>BDL2; BDL0.5</td>
<td>BDL10</td>
</tr>
<tr>
<td>Metoprolol</td>
<td>BDL10</td>
<td></td>
</tr>
<tr>
<td>Propanolol</td>
<td>BDL10</td>
<td></td>
</tr>
<tr>
<td>Ciprofloxacin</td>
<td>BDL50</td>
<td>BDL30</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>BDL50</td>
<td>BDL30</td>
</tr>
<tr>
<td>Norfloxacin</td>
<td>BDL50</td>
<td>BDL30</td>
</tr>
<tr>
<td>Ofloxacin</td>
<td>BDL30</td>
<td>BDL30</td>
</tr>
<tr>
<td>Trimethoprim</td>
<td>BDL1; BDL0.25</td>
<td>BDL30</td>
</tr>
<tr>
<td>Ibuprofen</td>
<td>BDL50</td>
<td>BDL10</td>
</tr>
<tr>
<td>Indometacine</td>
<td>BDL10</td>
<td></td>
</tr>
<tr>
<td>Ketoprofen</td>
<td>BDL10</td>
<td></td>
</tr>
<tr>
<td>Bisphenol-A</td>
<td>BDL5; BDL100</td>
<td></td>
</tr>
<tr>
<td>NDMA</td>
<td>BDL2; 2.8</td>
<td></td>
</tr>
<tr>
<td>Estrone</td>
<td>BDL0.5</td>
<td></td>
</tr>
<tr>
<td>17β-estradiol</td>
<td>BDL0.5</td>
<td></td>
</tr>
<tr>
<td>Ethinylestradiol</td>
<td>BDL0.5</td>
<td></td>
</tr>
<tr>
<td>Nonylphenol</td>
<td>BDL500</td>
<td></td>
</tr>
<tr>
<td>Acetaminophen</td>
<td>BDL5; BDL500</td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>19; BDL50</td>
<td></td>
</tr>
</tbody>
</table>

Sampling Information:
1. GAC1: Average of two sampling events; except NDMA (4 samples)
2. GAC2: One sample for some parameters; average of two samples for others
3. RO1: one sample
4. RO2: average of two samples
5. RO3: Average of 30 samples
6. RO4: Average of quarterly samples taken in two years
SUMMARY AND CONCLUSIONS

Balancing Costs and Benefits of Potable Reuse Treatment Technologies
Summary

• **Financial.** The capital and operating costs for the RO-based approach are 45% and 270% higher, respectively, than the GAC-based approach.
  - Difficulties with RO concentrate disposal can dramatically increase the cost of the RO-based approach

• **Environmental.** The RO-based approach produces more than twice the GHG emissions.

• **Water Quality:**
  - Both trains provide significant reduction of CECs, pathogens, nutrients, and bulk organic matter
  - RO-based approach produces lower concentrations of TOC; lower TOC not needed for GAC-based train, but could be provided with more frequent regeneration
  - The RO train, either in split-stream treatment mode or full-flow treatment mode, may be necessary at those locations that have unacceptable salinity (TDS)
Conclusions

• GAC-based treatment options cost less
• GAC and RO-based options perform similarly for most water quality parameters
• GAC-based treatment options may be appropriate in some cases
• Non RO-based options should be considered when planning potable water reuse
Questions?

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