Indirect Potable Reuse with Ozone, Biofiltration and Soil Aquifer Treatment

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Discussion Topics

• Background information
• Pilot plant description
• Test results
  – Bulk organic matter
  – Disinfection and disinfection byproducts
  – Trace organic contaminants (TOrCs)
• Conclusion
Types of Potable Reuse

Wastewater Treatment Facility → Surface Water → Water Treatment and Distribution System

*De facto* potable reuse
Types of Potable Reuse

Advanced Water Treatment Facility

Environmental buffer (aquifer or reservoir)

Indirect potable reuse

Water Treatment and Distribution System
Types of Potable Reuse

Direct potable reuse (DPR)

Advanced Water Treatment Facility → Engineered buffer → Water Treatment or Distribution System

Indirect potable reuse (IPR)

Environmental buffer (aquifer or reservoir)
California Groundwater Recharge Regulations

• Pathogen removal
  – Virus, *Cryptosporidium* & *Giardia*
  – Unit process requirements

• Total organic carbon limits
  – ≤ 0.5 mg/L of wastewater origin
  – Ratio of recycled water in recharge water
Recycled Water Content
Research Project

• Upper San Gabriel Valley Municipal Water District
  – Seeking to improve water supply with groundwater recharge by surface spreading

• Study objectives
  – Minimize TOC concentration
  – Evaluate factors affecting BAF performance
  – Measure disinfection and disinfection byproducts (DBP)
PILOT PLANT
San Jose Creek Water Reclamation Plant
Whittier, CA

- Los Angeles County Sanitation Districts
- Treatment (Title 22)
  - Nitrification/denitrification
  - Filtration
  - Chlorine disinfection
- Pilot plant source water
  - Secondary effluent before chlorination
Ozone System

Let’s solve tomorrow’s treatment challenges today. Let’s solve water.
Filter Pilots

FC-1

FC-2

FC-3

FC-4

FC-5
Filter Pilots

- **Filter media type**
  - FC-1 ➔ used GAC from UOSA
  - FC-2 & FC-3 ➔ Calgon Filtrasorb 300
  - FC-4 & FC-5 ➔ anthracite coal

- **Empty-bed contact time**
  - FC-1 = 19 minutes
  - FC-2 & FC-4 = 20 minutes
  - FC-3 & FC-5 = 10 minutes
Soil Columns

- Soil from near spreading basin
- Sieved to remove material > 2 mm
- HRT = 28 days each (56 days total)
- Upward flow
Process Flow Diagram

Test 5

Source Water

Ozonation

FC-1 (GAC)

FC-1 Effluent

FC-2 (GAC)

FC-2 Effluent

SC-1

SC-1 Effluent

SC-2

SC-2 Effluent

FC-3 (GAC)

FC-3 Effluent

FC-4 (Anthracite)

FC-4 Effluent

FC-5 (Anthracite)

FC-5 Effluent
PILOT TEST RESULTS – BULK ORGANIC MATTER

Model structure of humic acid (Stevenson, 1982)

Model structure of fulvic acid (Buffle et al., 1977)
Effect of Ozone and BAC on Fluorescence

Secondary Effluent
Effect of Ozone and BAC on Fluorescence

Secondary Effluent

Ozone Effluent

Humic acids

Proteins & SMPs

Fulvic acids

0.63 O3/TOC ratio
Effect of Ozone and BAC on Fluorescence

Secondary Effluent

Ozone Effluent

FC-1 Effluent
Effect of Ozone and BAC on Fluorescence

- Secondary Effluent
- Ozone Effluent
- FC-1 Effluent
- RO Permeate (WRRF 11-02)

Humic acids
Proteins & SMPs
Fulvic acids
0.63 O₃/TOC ratio
19-min EBCT
Effect of $\text{O}_3$/TOC on TOC removal

![Graph showing the effect of O$_3$/TOC on TOC removal. The graph compares the removal of TOC across different FC samples (FC-1 to FC-5) for different O$_3$/TOC ratios (Test 1: 0.75 O$_3$/TOC, Test 2: 1.00 O$_3$/TOC, Test 3: 1.25 O$_3$/TOC, Test 4: 1.50 O$_3$/TOC).]
Effect of EBCT on TOC Removal

- FC-2 vs. FC-3 "GAC"
- FC-4 vs. FC-5 "Anthracite"

TOC removal

Test 1 Test 2 Test 3 Test 4 Test 1 Test 2 Test 3 Test 4

EBCT=20 min (FC-2 and FC-4) EBCT=10 min (FC-3 and FC-5)
TOC Removal by SAT

![Bar chart showing TOC removal percentages for Test 1, Test 3, Test 4, and Test 5, with SC-1 and SC-2 categories.]
Total TOC Removal by $\text{O}_3\text{-BAC-SAT}$
Total TOC Removal by O$_3$-BAC-SAT

TOC = 2.0 mg/L
RWC = 25%

TOC = 1.9 mg/L
RWC = 26%

TOC = 1.7 mg/L
RWC = 29%

TOC = 1.4 mg/L
RWC = 36%

Average Sec. Eff. TOC = 6.1 mg/L
PILOT TEST RESULTS – DISINFECTION & DBPS
Total Coliform Removal

Test 1: O₃:TOC = 0.79
Test 2: O₃:TOC = 0.97
Test 3: O₃:TOC = 1.38
Test 5: O₃:TOC = 1.01

Total coliform concentration (Log(CFU/1000 mL))
NDMA removal by BAC

![NDMA removal graph showing](image_url)
NDMA removal by BAC

Measured NDMA after soil columns for Test 2:
81 ng/L (FC-1) → 4.1 ng/L (SC-1) and < 2 ng/L (SC-2)
Bromate Formation by Ozone

<table>
<thead>
<tr>
<th>Test</th>
<th>Concentration (µg/L)</th>
<th>O3/TOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>10</td>
<td>0.79</td>
</tr>
<tr>
<td>Test 2</td>
<td>90</td>
<td>0.97</td>
</tr>
<tr>
<td>Test 3</td>
<td>90</td>
<td>1.38</td>
</tr>
<tr>
<td>Test 5</td>
<td>90</td>
<td>1.01</td>
</tr>
</tbody>
</table>

MCL: 10 µg/L

Legend:
- Bromide (Sec Eff)
- Bromate (O3 Eff)
PILOT TEST RESULTS – TRACE ORGANIC CONTAMINANTS

Sulfamethoxazole

Carbamazepine

TCEP

DEET

Atenolol

Triclosan
## Trace Organic Contaminants

<table>
<thead>
<tr>
<th>&lt; MRL in Secondary Effluent</th>
<th>&lt; MRL after Ozone</th>
<th>Present After Ozone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaminophen</td>
<td>Atenolol</td>
<td>4-Nonylphenol</td>
</tr>
<tr>
<td>Atorvastatin</td>
<td>Azithromycin</td>
<td>Acesulfame-K</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>Carbamazepine</td>
<td>Carisoprodol</td>
</tr>
<tr>
<td>Caffeine</td>
<td>Diclofenac</td>
<td>DEET</td>
</tr>
<tr>
<td>Diazepam</td>
<td>Erythromycin-H2O</td>
<td>Fipronil</td>
</tr>
<tr>
<td>Iopromide</td>
<td>Fluoxetine</td>
<td>Galaxolide</td>
</tr>
<tr>
<td>Naproxen</td>
<td>Furosemide</td>
<td>Iohexol</td>
</tr>
<tr>
<td>Octylphenol diethoxylate</td>
<td>Gemfibrozil</td>
<td>Meprobamate</td>
</tr>
<tr>
<td></td>
<td>Ibuprofen</td>
<td>Phenytoin</td>
</tr>
<tr>
<td></td>
<td>Metoprolol</td>
<td>Primidone</td>
</tr>
<tr>
<td></td>
<td>Nonylphenol diethoxylate</td>
<td>Sucralose</td>
</tr>
<tr>
<td></td>
<td>Nonylphenol monoethoxylate</td>
<td>TCEP</td>
</tr>
<tr>
<td></td>
<td>Octylphenol monoethoxylate</td>
<td>TCPP</td>
</tr>
<tr>
<td></td>
<td>Propranolol</td>
<td>TDCPP</td>
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<tr>
<td></td>
<td>Sulfamethoxazole</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tonalide</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Triclocarban</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Triclosan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trimethoprim</td>
<td></td>
</tr>
</tbody>
</table>
TOrC Removal by Ozone

![Graph showing the removal by unit process of various chemicals using ozone.](Image)
Comparison of TOrC Removal by Ozone and BAC

<table>
<thead>
<tr>
<th>Compound</th>
<th>Removal by Ozone</th>
<th>Removal by BAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galaxolide</td>
<td>95%</td>
<td>85%</td>
</tr>
<tr>
<td>Phenytoin</td>
<td>90%</td>
<td>80%</td>
</tr>
<tr>
<td>Primidone</td>
<td>85%</td>
<td>75%</td>
</tr>
<tr>
<td>Fipronil</td>
<td>75%</td>
<td>65%</td>
</tr>
<tr>
<td>DEET</td>
<td>65%</td>
<td>55%</td>
</tr>
<tr>
<td>Carisoprodol</td>
<td>55%</td>
<td>45%</td>
</tr>
<tr>
<td>Iohexol</td>
<td>45%</td>
<td>35%</td>
</tr>
<tr>
<td>Meprobamate</td>
<td>35%</td>
<td>25%</td>
</tr>
<tr>
<td>4-Nonylphenol</td>
<td>25%</td>
<td>15%</td>
</tr>
<tr>
<td>Sucralose</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td>TCPP</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>TCEP</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>TDCPP</td>
<td>1%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Conclusions

• Achieved RWC as high as 36%
• Consider bromate formation control
• BAC can remove ozone-resistant TOrCs
• Next steps
  – Monitor TOrC removal through SAT
  – Consider other treatment trains
    • $O_3$-BAC-$O_3$-SAT
    • $O_3$-BAC-GAC-SAT
Acknowledgements

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Thank you!

Questions?

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