Simultaneous Removal of Cr(VI), Iron, & Manganese: Bench- to Full-scale in Under a Year

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CANV AWWA Fall Conference
Las Vegas, NV
October 27, 2015
Overview

• Problem description
• RCF/RCOF process description
• Implementation process
  – Bench- and pilot-testing
  – Full-scale design and construction
  – Permitting
  – Unforeseen challenges
• Cost comparison
Problem Description

• California Water Service (Cal Water) had a new 500 gpm Fe/Mn removal system
  – HLR 8.0 gpm/ft²
  – Typical 8 hours of operation prior to backwash
  – Discharge to sewer following equalization

• SBA-IX implemented at other Cr(VI) impacted sites in the district
  – Less than ideal at this location

• Significant cost savings could be realized if existing infrastructure could be utilized for simultaneous Cr(VI), Fe, and Mn treatment
## Existing Treatment and WQ

<table>
<thead>
<tr>
<th>Parameter (units)</th>
<th>Typical Raw Water Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total chromium (µg/L)</td>
<td>27</td>
</tr>
<tr>
<td>Cr(VI) (µg/L)</td>
<td>23</td>
</tr>
<tr>
<td>Iron (µg/L)</td>
<td>53</td>
</tr>
<tr>
<td>Manganese (µg/L)</td>
<td>43</td>
</tr>
</tbody>
</table>
Reduction Coagulation Filtration (RCF)

Ferrous → Reduction 30 min → Aeration → Filtration → Clearwell

Air Blower

Polymer feed TBD pending pilot testing

Chlorine (existing)

Backwash Water

Direct sewer discharge or mixed backwash EQ tank prior to sewer

Clearwell not required. Can supply BW from DS or other vessels in service

Reduction Coagulation Oxidation Filtration (RCOF)

Implementation Process: Bench-scale Testing (Sept 2014)

• Identified Cr(VI) reduction was faster than anticipated
• Near complete Cr(VI) removal was observed
  – 1 min contact time
  – 3 mg/L-Fe dose
• Mn not removed at bench-scale (as anticipated)
Implementation Process: Pilot-scale Testing (Jan 2015)

• Utilized the Pureflow pilot trailer
  – Four 6” columns
  – Common and independent chemical feed points
• Each column outfitted with reduction contactors
• 8-hr and extended filter runs conducted
Pilot-scale Testing
## Pilot-scale Testing

<table>
<thead>
<tr>
<th>Variable</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous Dose (mg/L-Fe)</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Reaction Time (min)</td>
<td>0, 1, 2, 5, 10</td>
</tr>
<tr>
<td>Chlorine Dose (mg/L)</td>
<td>0.5 – 1.0</td>
</tr>
</tbody>
</table>
Pilot-scale Results:
1 mg/L Ferrous, 1 & 5 min Reduction

- TotCr Inf, 1 min, 1 mg/L-Fe
- TotCr Eff, 1 min, 1 mg/L-Fe
- TotCr Inf, 5 min, 1 mg/L-Fe
- TotCr Eff, 5 min, 1 mg/L Fe

Elapsed Filter Run Time (min)

Total Chromium (µg/L)
Pilot-scale Results: 1 mg/L Ferrous, 1 & 5 min Reduction

Cr(VI) (µg/L) vs. Elapsed Filter Run Time (min)

- Cr(VI) Inf, 1 min, 1 mg/L-Fe
- Cr(VI) Eff, 1 min, 1 mg/L-Fe
- Cr(VI) Inf, 5 min, 1 mg/L-Fe
- Cr(VI) Eff, 5 min, 1 mg/L Fe
## Pilot-scale Results

### Backwash Character

<table>
<thead>
<tr>
<th>Sample</th>
<th>Backwash Concentration</th>
<th>Average Loading (ppd)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barium</strong></td>
<td>150 µg/L</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Chromium</strong></td>
<td>0.92 mg/L</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Vanadium</strong></td>
<td>0.17 mg/L</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Iron</strong></td>
<td>34 mg/L</td>
<td>1.95</td>
</tr>
</tbody>
</table>
Pilot-scale Summary

• Achieved all water quality objectives
  – Cr(VI) MCL compliance
  – Iron and manganese control

• Reduction times as short as 1 minute were successful

• Proceed with full-scale implementation (as quickly as possible!)
Full-scale Process Modifications

• Chemical addition and mixing:
  – Addition of ferrous storage and injection
  – Relocation of chlorine feed

• Reduction contactors
  – Piping configuration

• Process control sample ports
Full-scale Process Modifications
Full-scale start-up (Sept 2015)
Utility Perspective

• Challenged with implementing pilot scale findings at full scale at an extremely rapid pace
  – Permitting hurdles
  – Equipment procurement
  – Constructability challenges
  – Unforeseen water quality issues
  – Operator training and acceptance
How we approached permitting

As a utility, Cal Water strives to be a leader in both the local and industry community.

– Transparency with local agencies

– Open and frequent communication with DDW
Unforeseen challenges

- Equipment procurement
- Changes in source water quality
- Concerns of possible Cr(VI) spiking
Operational opinion

• Training and documentation

• Living with RCOF vs. Strong Base Anion Exchange
Cost Implications

SBA-IX (500 gpm)
- Pilot Testing: $20,000
- Equipment and Installation Cost: $900,000
- Total Cost: $920,000

RCOF Improvements
- Pilot Testing: $90,000
- Equipment and Installation: $300,000
- Total Cost: $390,000
Shout out to my Chromies

• Steve Vasquez, Mike Jones, and the entire operational staff (Cal Water)

• Rekha Ippagunta (Cal Water)

• Lifei Huang (UC Davis)

• Eli Townsend, Tarrah Henrie, Chad Seidel (Corona)
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