Chromium 6 Treatment Options

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Agenda

• Introduction
• Regulatory Update
• Leading Technologies
• Key Technology Selection Drivers
• Conclusions
What is Chromium 6 and why is it a new regulatory concern?

- Chromium – Cr3 and Cr6 – is a naturally occurring element found in rock, soil, and groundwater.
- Cr3 is an essential human nutrient that is included as an element in food supplements.
- Cr6 can also occur as an industrial byproduct in manufacturing processes.
- These industrial byproducts were discharged to the ground, in rivers, etc. and eventually reached groundwater supplies.
Cr₃ may be converted to Cr₆ if not removed.
What is the new draft California MCL for Cr6?

- Cr6 concentration of 10 ppb
- Regulated at points of entry
- Quarterly running annual average
- Best available technologies include:
  - Ion exchange
  - Coagulation/filtration (with reduction upstream)
  - Reverse osmosis
- CDPH can require chromium speciation study if monitoring results exceed 10 ppb and disinfection is used
Will USEPA set a Cr6 MCL?

- **UCMR3 – 2013-2015**
  - Assessment Monitoring List includes Cr6 and Total Cr
    - Low detection limits
    - Entry point and maximum detention time location
    - Ground water – monitor twice in a 1 year period
    - Surface water – monitor quarterly in a 1 year period

- **IRIS Toxicological Review underway**
What are important lessons learned from implementation of the Arsenic Rule?

- Careful selection of technologies is important, because some of the best available technologies may not work effectively in every water quality.

- Residuals disposal was the tail that wagged the dog.

- Costs were underestimated.

- Many small communities are still out of compliance.
What are the options for achieving Cr6 MCL compliance?

- Non-treatment
  - Blending
  - Use of other sources

- Treatment
Four treatment strategies emerged as leading options – All can achieve the draft MCL of 10 ppb

- Weak-Base Anion Exchange
- Strong-Base Anion Exchange with Residuals Treatment
- Reduction/Coagulation/Filtration
- Reverse Osmosis
Operational experience with WBA and RCF at Glendale, California

- Glendale chose to design and construct WBA and RCF removal facilities to treat their groundwater
- SBA not selected due to concerns about long-term brine disposal
Operational experience with SBA at Coachella Valley Water District

- CVWD is operating three SBA facilities (up to 4,000 gpm) for arsenic removal, and also observing removal of Cr(VI) to less than 1 ppb
- Brine treatment and disposal is cost driver
Weak Base Anion Exchange (WBA) treatment process

- Cr6 exchange and conversion to Cr3
- Requires pre- and post-treatment for pH control
WBA unit processes

Raw Water

CO₂ or Acid

Bag filters

Resin vessels

Aeration or Caustic

Treated Water
Strong Base Anion Exchange (SBA) treatment process

- Exchange of Cr(VI) anions for less strongly held chloride ions on resin beads

- Requires periodic regeneration with salt solution (brine) and disposal and/or treatment of Cr(VI)-laden brine
SBA unit processes

RAW WATER

BAG FILTERS

RESIN VESSELS

TREATED WATER

BRINE TANK

PUMP

SPENT BRINE AND SLOW RINSE TO TREATMENT

BACKWASH AND FAST RINSE TO SEWER
SBA brine treatment
SBA brine treatment

SPENT BRINE AND SLOW RINSE WASTE WATER

GRAVITY THICKENING TANK

PUMP

AIR BLOWER (INTERMITTENT)

DEWATERING

SLUDGE PUMP

SUPERNATANT

FERROUS SULFATE STORAGE & HANDLING SYSTEM

POLYMER STORAGE & HANDLING SYSTEM

WASTEWATER TANK

TRUCK OFF

FILTRATE

PUMP

SOLIDS TO LANDFILL

PUMP
Reduction/Coagulation/Filtration (RCF) treatment process

- Use of ferrous iron to reduce Cr6 to Cr3
- Removal of particle-bound Cr3
Reduction/Coagulation/Filtration (RCF) treatment process

Fe$^{II}$SO$_4$ → Fe$^{III}$(OH)$_3$
Cr(VI) → Cr(III)

Reduction Coagulation Filtration

Reduction  Coagulation  Filtration
RCF unit processes

- Raw Water
- Ferrous iron
- Reduction
  - Oxidation of ferrous with air or chlorine
    - Polymer if granular media
      - Filtration
        - Backwash
          - Backwash waste
        - Treated Water
RCF – with granular media filtration
RCF – with microfiltration

Microfiltration: Submerged and Pressure
Reverse Osmosis (RO) treatment process

- Use of high pressures to exclude chromium molecules through size and charge exclusion

- Requires pretreatment chemical dosing to avoid scaling

- Will require downstream blending or mineral addition to avoid distribution and service pipe corrosion
RO unit processes

Raw Water → Acid (if needed) → High-pressure membranes → Concentrate → Blending or post-treatment → Treated Water

Scale Inhibitor
Key deciding factors in technology selection

- Water Quality
- Residuals Disposal
- Operational Preferences and Flexibility
- Cost Considerations
Impacts of water quality of technology selection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Impact</th>
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<tbody>
<tr>
<td>Alkalinity</td>
<td>High alkalinity increases CO$_2$ or acid doses needed for pH reduction on WBA resin</td>
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<tr>
<td>Sulfate</td>
<td>High sulfate increases brine generation rate for SBA resin</td>
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<tr>
<td>TOC</td>
<td>High TOC can impact RCF coagulation, requiring smaller particle size removal</td>
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<tr>
<td>Uranium</td>
<td>One WBA resin effectively accumulates uranium</td>
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Residuals for each technology

**WBA**
- Minimal backwash water
- Spent resin

**SBA**
- Brine
- Precipitated Cr from brine

**RCF**
- Backwash water (3-5%)
- BW water solids if settled

**RO**
- Concentrate (15-25%)
- None
Operational preferences and flexibility

- Time
- Systems complexity
- Operator level
Three sets of cost estimates used to develop this specific example.

Treatment process assumptions:
- SBA - On-site regeneration with brine
- RCF - 45 minute reduction time and aeration (for bars)
- RCMF - 15 minute reduction time and chlorination
- WBA - pH adjustment with CO₂ and air stripping

Residuals management assumptions:
- SBA clarified waste brine hauled off-site
- RCF backwash water treated and recycled
- RCMF backwash water discharged to sewer
O&M costs – An example

Assumptions:

- Assumes water quality of approximately 20 mg/L sulfate and 165 mg/L alkalinity
- Assumes 100% utilization for O&M costs
Annualized costs – An example

Assumptions:

• 20 year equipment life
• 5% interest rate
Summary

• New draft Cr(VI) MCL in California of 10 ppb

• Research identified several possible technologies for Cr(VI) removal to achieve this MCL
  – Ion Exchange (weak- and strong-base)
  – Reduction/Coagulation/Filtration
  – Reverse Osmosis

• Key drivers for technology selection are water quality, residuals disposal options, operational preferences, and cost
Reference Materials

City of Glendale Final Report (February 28, 2013)

Available on City website

Water Research Foundation sponsored study – Guidelines for Hexavalent Chromium Treatment Studies, #4418

Available on WaterRF website
Questions?

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