RECLAMATION

Managing Water in the West

Rural and Small Community Chrome Removal Applications

Research and Development Office
Advanced Water Treatment Program
Final Report ST-2015–1759-1

Miguel Arias-Paic

U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

October 2015

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

REPORT DOCUMENTATION PAGE					Form Approved OMB No. 0704-0188
T1. REPORT DATE October 2015		**T2. REPORT TYPE** Research			**T3. DATES COVERED**
T4. TITLE AND SUBTITLE Rural and Small Community Chrome Removal Applications					**5a. CONTRACT NUMBER**
					5b. GRANT NUMBER
					5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Miguel Arias-Paic					**5d. PROJECT NUMBER** 1759
					5e. TASK NUMBER
					5f. WORK UNIT NUMBER 86-68190
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Miguel Arias-Paic, Bureau of Reclamation, Technical Service Center, Water Treatment Group 86-68190, PO Box 25007, Denver CO 80225-0007					**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Research and Development Office U.S. Department of the Interior, Bureau of Reclamation, PO Box 25007, Denver CO 80225-0007					**10. SPONSOR/MONITOR'S ACRONYM(S)** R&D: Research and Development Office BOR/USBR: Bureau of Reclamation DOI: Department of the Interior
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION / AVAILABILITY STATEMENT Final report can be downloaded from Reclamation's website: https://www.usbr.gov/research/					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT *(Maximum 200 words)*					

The California Department of Public Health adopted a hexavalent chromium maximum contaminant level of 0.010 mg/L that became effective on July 1, 2014. Historical sampling for Title 22 at Joshua Basin Water District indicated that several wells were above this chromium VI maximum contaminant level. These results prompted the District to evaluate different options: treatment, blending and well profiling for mitigating the hexavalent chromium to below regulatory concentrations. Reclamation was tasked with determining optimal treatment options and evaluating them at the pilot scale.

Pilot treatment processes currently being conducted at Joshua Basin water, using both weak base ion exchange resin (disposable) and strong base ion exchange resin (regenerable). The weak base resin is being tested for chromium and uranium content to determine disposal costs and handling. The strong base resin is being tested and brine used during regeneration is being fractionated using salt concentration staged regeneration, membrane separation (recycled, waste and recycled components of brine) and membrane concentration of waste.

15. SUBJECT TERMS Rural Water, Small Community, Chromium VI					
16. SECURITY CLASSIFICATION OF: U			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Miguel Arias-Paic
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	U	13	**19b. TELEPHONE NUMBER** 303-445-2132

PEER REVIEW DOCUMENTATION

Project and Document Information

Project Name Rural and Small Community Chrome Removal Applications WOID Z1759

Document Rural and Small Community Chrome Removal Applications

Document Author(s) Miguel Arias-Paic Document date October 2015

Peer Reviewer Matt Hirschbeck

Review Certification

Peer Reviewer: I have reviewed the assigned items/sections(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer ____________________________________ Date reviewed 10/20/2015
(Signature)

Contents

Executive Summary

The California Department of Public Health adopted a hexavalent chromium maximum contaminant level of 0.010 mg/L that became effective on July 1, 2014. Historical sampling for Title 22 at Joshua Basin Water District indicated that several wells were above this chromium VI maximum contaminant level. These results prompted the District to evaluate different options: treatment, blending and well profiling for mitigating the hexavalent chromium to below regulatory concentrations. Reclamation was tasked with determining optimal treatment options and evaluating them at the pilot scale.

Pilot treatment processes currently being conducted at Joshua Basin water, using both weak base ion exchange resin (disposable) and strong base ion exchange resin (regenerable). The weak base resin is being tested for chromium and uranium content to determine disposal costs and handling. The strong base resin is being tested and brine used during regeneration is being fractionated using salt concentration staged regeneration, membrane separation (recycled, waste and recycled components of brine) and membrane concentration of waste.

Introduction

The California Department of Public Health adopted a hexavalent chromium maximum contaminant level of 0.010 mg/L that became effective on July 1, 2014. Historical sampling for Title 22 at Joshua Basin Water District indicated that several wells were above this chromium VI maximum contaminant level. These results prompted the District to evaluate different options: treatment, blending and well profiling for mitigating the hexavalent chromium to below regulatory concentrations. Reclamation was tasked with determining optimal treatment options and evaluating them at the pilot scale.

The treatment process currently being implemented at all Joshua Basin ground water wells is solely chlorination of raw water at the well heads. The chlorination has no impact on hexavalent chromium concentrations. Of note is that all other treated water quality parameters besides hexavalent chromium meet regulatory compliance. In considering the best treatment technology to mitigate hexavalent chromium factors such as cost, existing treatment processes, additional treatment benefit (such as organic carbon removal), process throughput, and waste production need to be considered to best tailor a solution to the existing infrastructure.

Process Selection Methodology and Pilot Testing Locations

The best available technologies, as defined by the Environmental Protection Agency for hexavalent chromium removal are: 1) absorbent disposable media, 2) conventional treatment (e.g. reduction / coagulation / filtration), 3) membrane separation (nanofiltration and reverse osmosis) and 4) ion exchange. Of the best available technologies, ion exchange was selected for hexavalent chromium testing at Joshua Basin due to 1) minimal waste production(less than 0.05% of the raw water treated), 2) minimal process footprint at full build out and 3) no additional water treatment processes were required, since in general the potable water sources at Joshua Basin are of good quality.

Reclamation's Technical Service Center was provided with historical Joshua Basin water quality, which is summarized in Table 1.

Table 1: Raw water quality at Joshua Basin Wells

Well	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	HCO_3 (mg/L)	CL (mg/L)	SO_4 (mg/L)	NO_3 (mg/L)	Cr VI (µg/L)
10	18	5.1	33	1.7	130	15	14	16	11.6
14	16	3.9	43	1.9	140	14	23	11	17.3
15	32	3.7	55	1.7	110	15	120	11	17.0
16	10	1.3	37	1.4	100	7.2	8.5	12	34.0
17	11	2.8	41	2.4	120	12	15	13	24.3

Several wells (10, 14, 16 and 17) within the basin have similar water quality in terms of competing anions (sulfate, nitrate and bicarbonate), which need to be taken into consideration when implementing an ion exchange process. These competing anions shorten the throughput until ion exchange exhaustion with respect to hexavalent chromium. Of the wells with similar water quality (10, 14, 16 and 17), 16 had the highest hexavalent chromium concentration, and well 14 had the highest sulfate concentration. Well 15 had the highest sulfate concentration across all wells – at least 5 times greater than the next highest sulfate concentration. The presence of sulfate at well 15 would require testing of both weak and strong base ion exchange resin, where the weak base resin is selective for chromium VI, allowing competing ions (sulfate, bicarbonate and nitrate) to pass through the column. Wells 10, 14, 16 and 17 would only be testing strong base ion exchange resin. The ion exchange resins considered for the testing process were weak and strong base anion exchange resin, both manufactured by the Purolite Corporation, where both are currently being used at full-scale installations.

Weak Base Ion Exchange

The weak base anion exchange resin requires pH adjustment down to approximately 5.5 prior to raw water contacting the resin, and also requires caustic pH adjustment for distribution system corrosion control following ion exchange treatment. The capacity of the weak base resin is relatively high (in the tens, if not hundreds of thousands of bed volumes) prior to hexavalent chromium breakthrough. When the resin is exhausted, it is sluiced out and disposed of as a solid waste product. Although uranium is non-detect in the wells at Joshua Basin, what typically governs the bed volume throughput of the weak base resin is how much uranium is ion exchanged onto the resin, since low level radioactive concentrations could accumulate, increasing the cost of resin disposal above certain radioactive thresholds. The weak base resin pilot testing is solely to be conducted at well 15, due to the elevated sulfate concentration.

Strong Base Anion Exchange

Strong base resin does not require any pH adjustment prior to contacting the ion exchange resin, but the selectivity for chrome is greatly reduced compared to weak base resin, where throughput is approximately 10,000 to 50,000 bed volumes prior to hexavalent chromium breakthrough, depending on the competing anion (sulfate, bicarbonate, nitrate) concentrations. The resin can be regenerated and used over multiple regeneration cycles, where the brine waste is the fraction that has to be dealt with and disposed of.

Current and Ongoing Testing

Testing for strong and weak base ion exchange is currently ongoing at well 15:

- Estimated completion date 10/2016
- Three pilot columns (2” PVC) are being tested: one with strong base resin, two with weak base resin
- Bi-weekly hexavalent chromium samples are being collected, up to tri-weekly samples on the strong base ion exchange resin column (only when breakthrough is imminent)
- Loading rates to be tested (headloss dependent; between 8 and 15 gpm/ft^2 for the strong base resin)

- Multiple regeneration cycles to be performed to limit the influence of virgin resin on process performance for the strong base resin
- Cycles until breakthrough are estimated to be up to 7,000 bed volumes for the strong base resin
    - 7,000 bed volumes would last up to 3 weeks, depending on the loading rate
- Reclamation will regenerate the strong base resin columns with sodium chloride brine, using multiple regeneration approaches focused on decreasing the volume of waste to be disposed of
- For the two weak base columns, both loading rate (between 8 to 12 gpm/ft^2) and pH (between 5.0 and 6.5) will be tested
- Cycles until breakthrough are estimated to be 100,000+ for the weak base resin, which could take 10 months+
    - Exhausted weak base resin will be analyzed for both uranium (uranate) and hexavalent chromium concentrations to determine the character of the waste and operational limitations in resin disposal.

Testing for strong base ion exchange is currently ongoing at well 16:

- Estimated completion date 10/2016
- Three pilot columns (2” PVC) are being tested: one with strong base resin, two with weak base resin
- Bi-weekly hexavalent chromium samples are being collected, up to tri-weekly samples on the strong base ion exchange resin column (only when breakthrough is imminent)
- Loading rates to be tested (headloss dependent; between 8 and 15 gpm/ft^2)
- Multiple regeneration cycles to be performed to limit the influence of virgin resin on process performance
- Cycles until breakthrough are estimated to be up to 30,000 bed volumes
    - 30,000 bed volumes would last up to 3 months, depending on the loading rate
- Reclamation will regenerate the columns with sodium chloride brine and determine waste fractions, using multiple brine approaches focused on decreasing the volume of waste to be disposed of

Testing for strong base regenerant brine reduction:

- Bench scale nanofiltration experiments were conducted on all waste brine from the pilot scale test sites at Joshua Basin
- Brine constituents had significantly different levels of chrome and competing ions (nitrate, sulfate and bicarbonate)
- Preliminary bench scale experiments recovered 60% of the brine waste as reusable sodium chloride brine useful for IX regeneration
- At the brine recovery fraction between 60% and 85%, brine high in larger anions but low in chromate and uranium was produced that was suitable for recycle to the plant headworks

- The remaining 10% by volume was a concentrated chromate/uranate brine requiring disposal
- Brine fractionation allowed for the two most significant operational expenditures of full-scale IX facilities to be greatly reduced; disposal costs were reduced by 90% and salt costs by 45%