Serving Potable Water from an Extremely Impaired Groundwater Superfund Source

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INTRODUCTION

Groundwater at a Southern California Superfund site is contaminated with perchlorate concentrations up to 260 micrograms per liter (µg/L) at a capture well and higher concentrations upgradient. The California primary Maximum Contaminant Level (the drinking water standard and groundwater cleanup goal) for perchlorate is 6 µg/L. The remedy involves groundwater extraction, treatment, and discharge to local potable water supply. Ion exchange (IX) is often the best available treatment technology for groundwater contaminated by perchlorate. However, because the State of California has never before permitted treatment of water with perchlorate concentrations greater than 50 µg/L for distribution as municipal water supply, the state regulator required a pilot study to evaluate the safety, viability, and predictability of IX treatment for this application. To provide added redundancy and safety, the full-scale plant and pilot test apparatus have a triplex (lead, mid and lag vessel/column) design as shown on Figure 1. This allows for safe treatment of high influent concentrations and more fully exhausts resin treatment capacity in the lead vessel/column.

Figure 1

INITIAL PILOT TEST

In an initial pilot test, perchlorate breakthrough occurred much earlier than predicted by resin vendor modeling. A comprehensive forensic analysis determined that premature breakthrough was caused by calcite precipitation within the pilot treatment columns due to long hold times of extracted groundwater in storage tanks, allowing CO_2 off-gassing and/or temperature fluctuations.

SECOND PILOT TEST

To confirm that calcification would not impact full-scale performance where water essentially flows continuously through the treatment process without extended hold times, a second pilot test, configured to better reflect those conditions, was performed. In addition, to maximize operational flexibility during full-scale operations, the second pilot test included parallel testing of three different gel resin IX media (Calgon CalRes 2122, Evoqua PSR2 Plus, and Purolite A532E). The second pilot test utilized a continuous flow process which eliminated CO_2 offgassing and minimized temperature change.

The second pilot test consists of two phases:

- Phase I which runs through "breakthrough" (4 µg/L perchlorate in the mid column effluent).
- At that point, the lead column is changed out, a new lag column with new media is introduced, and the former mid and lag columns are moved up in series to start Phase II.

On January 16, 2018, AECOM commenced implementation of the second pilot test. Weekly influent Perchlorate concentrations have ranged between 69 and 180 µg/L (during the second test) with an average concentration of about 130 µg/L.

Since startup, samples have been collected on a weekly basis from each of the three columns of the three pilot treatment trains, every third-week sample is submitted for perchlorate analysis, until perchlorate is detected in the lead column effluent.

As of February 5, 2019, perchlorate has been detected in the lead column effluent of all three treatment trains and the mid column effluent of two treatment trains. Initial detections are shown in Table 1.

Breakthrough occurred in the lead column effluent of all three treatment trains and the mid column effluent of two treatment trains as shown in Table 2.

A graph depicting perchlorate concentration versus throughput for the lead and mid column effluent of each pilot treatment train is presented on Figure 2.

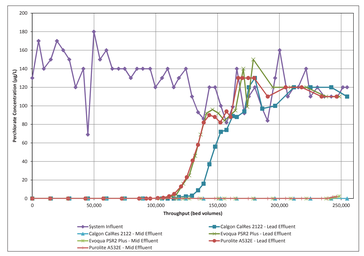
Table 1 - Initial Detection

Vendor	Column	Date	Bed Volumes	Throughput (gallons)	Perchlorate Concentration (µg/L)
Calgon	Lead	7/2/2018	118,673	313,348	1.7
	Mid	No Detection as of 2/5/2019			
Evoqua	Lead	6/19/2018	107,545	292,815	0.58
	Mid	1/9/2019	245,418	671,875	1.4
Purolite	Lead	6/13/2018	101,980	277,662	0.52
	Mid	1/9/2019	243,106	661,910	1.6

Table 2 - Breakthrough

Vendor	Column	Date	Bed Volumes	Throughput (gallons)	Perchlorate Concentration (µg/L)
Calgon	Lead	7/24/2018	134,208	354,369	8.9
	Mid	No Detection as of 2/5/2019			
Evoqua	Lead	7/2/2018	116,587	317,433	4.2
	Mid	1/22/2019	253,717	694,594	5.6
Purolite	Lead	7/2/2018	114,850	312,705	5.0
	Mid	1/22/2019	251,485	684,723	4.5

Figure 2 - Lead Column Perchlorate Concentration vs. Throughput



Pressure Drop Considerations

After the initial approximately 10,000 bed volumes (BVs), pressure drops (dPs) across each pilot treatment train have increased fairly linearly by about 5 to 10 psi. Individual column and total train dPs versus throughput for each treatment train are presented on Figures 3a, 3b, and 3c.

Following maintenance to address fine material, believed to have passed through the 10-µm filters following an unplanned power outage, by exercising valves, cleaning flow tubes, and replacing the pressure gauges on all three lead columns, the lead column and total train dP readings (i.e., the inflections in slopes visible at ca. 160,000 BVs) dramatically dropped for all three trains. In the subsequent months, the lead column and total dPs for all three trains have fallen roughly back onto the same trend lines as measured prior to the power outage.

Figure 3a - Calgon Pressure Drop vs. Throughput

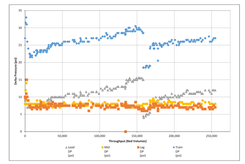


Figure 3b - Evoqua Pressure Drop vs. Throughput

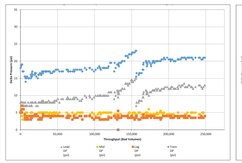


Figure 3c - Purolite Pressure Drop vs. Throughput

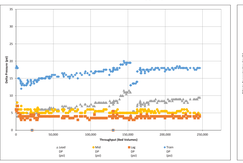
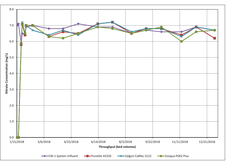


Figure 4 - Nitrate vs. Throughput



A common concern with IX resin is the potential to slough nitrate (i.e., when effluent nitrate concentrations exceed influent nitrate concentrations), so nitrate testing has been performed throughout Phase I. The results are depicted on Figure 4 and indicate that no nitrate sloughing has occurred.

Phase I Results – All Three Resins Reliably and Effectively Treated High Perchlorate Concentrations

- Design changes to the second pilot test appear to have eliminated the calcite precipitation issue.
- Perchlorate concentrations in the lead and mid columns (Figure 2) display smooth breakthrough curves and have generally followed expected IX resin performance as predicted by the vendors.
- After the initial approximately 10,000 BVs (and the maintenance event after the power outage), dPs across each pilot treatment train's lead column have increased fairly linearly by about 5 to 10 psi over the course of the second pilot test to date. dPs across mid and lag columns have increased on the order of a few psi since the first ~10,000 BVs.
- Perchlorate has not been detected in lag column effluent at any time.
- As of the conference, approximately 300,000 BVs have been treated through each of the 3 individual treatment trains.
- There has been no nitrate sloughing to date.
- Competing ions broke through within the first 6,000 BVs and effluent concentrations have essentially been equal to effluent ever since.
- Uranium broke through all columns of each train between 146,000 and 205,000 BVs. Effluent concentrations have been roughly equal to influent concentrations subsequently.
- Nitrosamine testing show no unacceptable concentrations in samples collected during the first day of pilot testing.
- Phase II will represent typical full-scale operation.
- Based on testing to date, the proposed full-scale IX treatment with any of the pilot-tested media should be reliable, effective and safe.