Ion Exchange and Disposal Issues Associated With the Brine Waste Stream

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The City of Arcadia recently completed construction of a new 1.5-mil-gal-per-day (mgd) water treatment plant (WTP) using ion exchange technology to replace its 3-mgd lime softening WTP. The lime plant had reached the end of its serviceable life and the treatment of groundwater for the removal of radionuclides, hardness, sulfides, organic carbon, and fluoride was desired in order to provide safe drinking water to the community. After evaluating several treatment technologies, including lime treatment, nanofiltration, ion exchange, and purchases from the local water supply authority, it was determined that ion exchange would be the most cost-effective option for construction. A reduction in capacity was also provided since the City's water supply source, groundwater from the intermediate aquifer, was limited based on current pumping limitations and permitted capacity.

The groundwater is supplied from six wells, approximately 350 ft deep and located within a 1-mi radius of the plant. A summary of the water quality from the wellfield is shown in Table 1.

Table 1. Arcadia Groundwater Quality

Parameter	Result	unit
Sulfide	1.58	mg/L
Iron	0.03	mg/L
Color	11	units
Turbidity	0.5	NTU
Alkalinity	220	mg/L
Calcium Hardness	47	mg/L
Chloride	19	mg/L
Fluoride	2.26	mg/L
Hardness	258	mg/L
Sulfate	20	mg/L
Total Organic Carbon (TOC)	5.2	mg/L
Aluminum	<0.02	mg/L
Sodium	31	mg/L
Gross Alpha	26	pCi/L
Radium 226	9	pCi/L
Radium 228	1	pCi/L
Bicarbonate Alkalinity	220	mg/L

In reviewing the groundwater quality, reduction in radium 226 and gross alpha is necessary to meet primary drinking water standards. Reduction in fluoride, sulfide, total organic carbon (TOC) and hardness is also desired to meet secondary standards and reduce the chlorine demands caused by the presence of sulfides and TOC, as well as minimize the formation of disinfection byproducts.

The use of ion exchange was determined to be the most cost-effective treatment for radionuclides. Cation exchange is commonly used for the removal of radionuclides and hardness. Anion exchange could also be provided for the removal of sulfides, organic carbon, and possibly, some fluoride. However, since ion exchange can utilize a significant amount of salt in its process and during regeneration, there were concerns as to how much salt would be added to the wastewater system based upon the amount of water treated.

In order to develop a better understanding of the process, pilot testing was performed. The test results could then be used to determine the effectiveness of the anion and cation exchange resins, blending requirements, runtime lengths, headloss, and brine regeneration requirements. In setting up the pilot test, maximum contaminant levels (MCLs) and target concentrations for the WTP were developed, as shown in Table 2. The objectives of the pilot study were to examine the ability of the cation exchange system to consistently achieve softening and radium removal. It was also to examine the ability of the anion exchange system to adequately remove sulfide and total organic carbon, with the addition of aeration to bio-

Table 2. Maximum Contaminant Level and Target Reduction

Parameter	Average Value	MCL	Target Goal	Unit	Desired Reduction	Regulation
Radium 226	9	5	-	pCi/L	50%	FAC 62-550
Hardness	258	-	129	mg/L	50%	Control Scaling
Total Sulfide[1]	1.58		0.30	mg/L	81%	FAC 62-555.315(5)a
TOC	5.2	-	2.0	mg/L	62%	Indirect DBP Rule
Fluoride	2.26	2.00	-	mg/L	12%	FAC 62-550

[1] Total sulfide will need to be reduced to less than 0.3 mg/L for raw water coming from any new production well.

logically promote the conversion of sulfide to sulfate.

The pilot equipment consisted of a reduced-scale ion exchange testing apparatus provided and assembled by Tonka Equipment Company, as shown in Figure 2. The study was conducted over a 30-day period, with approximately six hours of runtime each day. The desired flow rate and runtime for the cation exchange column was 6.5 gal per hour (gph) for 24 hours, resulting in 160 gal of treated water. The anion exchange column desired flow rate and runtime was 8.1 gph for 65 hours, yielding 525 gal of treated water. Two complete brine regenerations were performed prior to the first run in order to ensure that the resin was in a chloride form.

To simulate the designed full-scale softening cation exchange vessel, an 8-ft-tall, 2-in.-diameter column was filled to a depth of 60 in. with Thermax T-42 Na high-capacity strong acid resin. A gage and pressure reducing valve were provided on the inlet line to monitor and control column pressure. Headloss was measured by an additional gage connected between the columns influent and effluent lines. Rate of flow control and a flow meter were plumbed into the column's discharge so as to maintain a constant treatment flow rate.

Similarly, a full-scale anion exchange vessel, with a 5-ft-tall, 2-in.-diameter column was filled to a depth of 36 in. with Thermax A-72 MP high-capacity strong base resin. A gage and pressure reducing valve was provided on the inlet line to monitor and control column pressure. Headloss was measured by an additional gage connected between the column's inlet and discharge lines. Rate of flow control and flow meter are plumbed to the column's discharge so as to maintain a constant treatment flow rate.

The testing apparatus was set up according to the pilot test protocol. The blended water was then aerated with .05 cu ft per hour (cfh) of air. The oxygen is used to help maintain conditions that are favorable to bacteria that can biologically oxidize the sulfide. The flow then passes through the anion exchange column where sulfide and organics are reduced. The anion exchange column received and processed all of the 6.5 gph of blended water, simulating the conditions of the full-scale process. Based on the pilot testing results, it was confirmed that significantly longer runtimes could be achieved by providing an environment conducive to the biological oxidation of sulfides. Based on these results, the estimated salt usage was determined to be significantly less than originally assumed for the anion units, while still achieving the water quality goals.

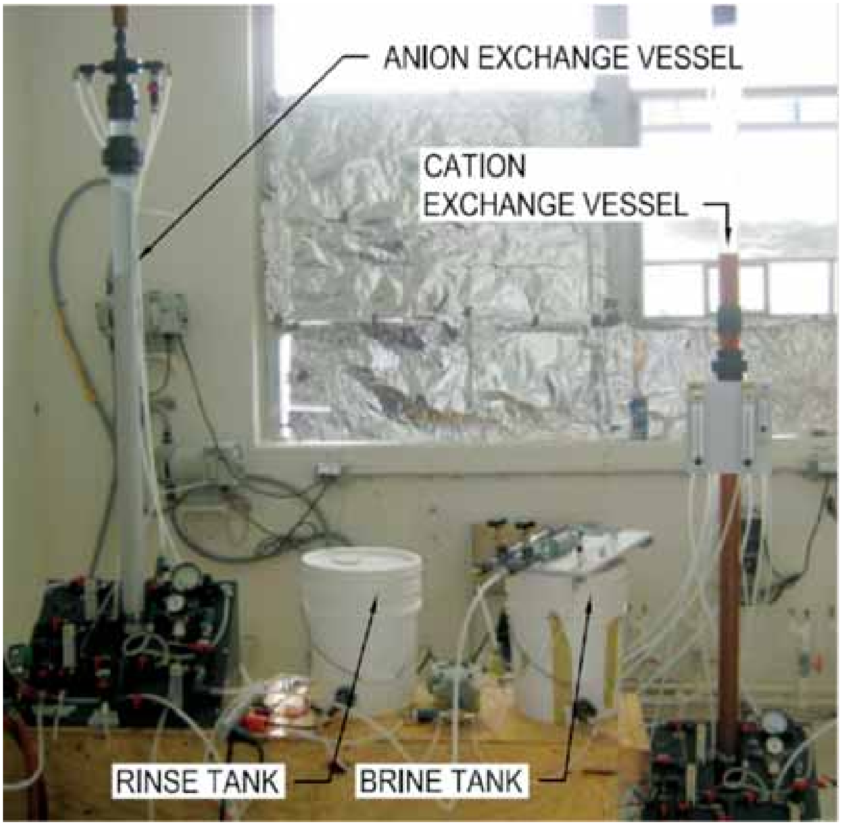

Figure 1. Pilot Test Equipment

Table 3. Anticipated Water Quality From Water Treatment Plant

Parameter	Concentration (mg/L)
Radium 226	<5
Hardness	130
Total Sulfide	<0.2
TOC	<2
Fluoride	2
Sodium	90

Using the data obtained by the pilot testing, it was determined that if 40 percent of the groundwater could be bypassed around the cation exchange system and recombined prior to the anion exchange system, all the water or percentage thereof could then receive treatment through the anion exchange columns. This would result in significantly reduced sulfide and TOC concentration, which would result in a lower chlorine demand. Using a blend of 60 percent cation and 100 percent anion, it was estimated that approximately 1,800 lbs of salt would be required to treat 1 mil gal (MG) of water. The resulting anticipated water quality would meet regulatory standards and the city's water quality objectives, shown in Table 3. However, the impact on the wastewater plant still needed to be evaluated.

The City's wastewater plant is a 2-mgd trickling filter plant with high-level disinfection to provide public access reuse. The plant provides reclaimed water to orange groves, a golf course, cemetery, parks, and residential customers, with a backup surface water discharge for wet weather. High concentrations of salt in irrigation waters can be problematic, since salt can reduce crop productivity. This is primarily caused by less water being available to the plant due to competing ions. High salt concentrations can also cause soils to become sodic, resulting in a degraded soil structure, which can prevent the plant from absorbing the water. Therefore, the amount of salt that

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Figure 2. New Arcadia Ion Exchange Water Treatment Plant

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would be added to the wastewater plant as a result of the ion exchange process was a significant concern.

Although, the discharge of the ion exchange waste stream is not specifically regulated by the Florida Department of Environmental Protection (FDEP), since it is not considered as an industrial waste, the requirements for the blending of demineralization concentrate with reclaimed water were evaluated. The FDEP Rule 62-610.875 (13) FAC, Blending of Demineralization Concentrate with Reclaimed Water, indicates that the addition of concentrate shall not impair the ability of the treatment facility to meet reclaimed water limitations, or harm vegetation grown in the reuse system. It also indicates that the reuse system must comply with groundwater standards at the edge of the zone of discharge. Therefore, these factors were evaluated to verify that the discharge of the brine waste would be acceptable to the reclaimed water system.

In evaluating the impact of the salt on the wastewater plant, the amount of salt being added to the system and the historical sodium and chloride concentrations of the wastewater effluent were evaluated. This analysis showed that the sodium and chloride values in the effluent varied based on season, with sodium and chloride concentrations being higher during the dry seasons. This data was then used to predict sodium and chloride concentrations for the treated wastewater effluent. The predicted sodium concentrations ranged from 100 mg to 170 mg/L and the predicted chloride levels ranged from 130 mg/L to 260 mg/L.

In reviewing the anticipated water quality, it was noted that the average sodium and chloride concentrations would meet the water quality standards of 160 mg/l sodium and 250 mg/l chloride. In addition to the sodium and chloride concentrations, the sodium adsorption ratio (SAR) was also evaluated. The SAR is a measure of the suitability of water for use in agriculture based on concentrations of solids dissolved in the water, which is calculated as follows:

$$SAR = [Na^+] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}$$

Waters with SAR >6 can cause negative impact to vegetation by limiting adsorption of water through soil. The SAR based on the proposed water quality was determined to be 4.5, which was less than 6 and therefore should not negatively impact the agricultural reclaimed water users.

Based on the pilot test results and preliminary engineering study, it was determined that the disposal of the brine would not cause any significant issues to the wastewater plant. Therefore, the City commenced construction on the new 1.5-mgd ion exchange WTP in January 2012. The new plant (Figure 2) was recently completed, with water production initiating in January 2013. The plant is currently producing approximately 0.7 mgd, since the facility is also accepting treated water from DeSoto County to assist in reducing flushing and maintaining flow in its system.

The water produced from the plant is currently meeting all water quality standards, treating 60 percent of the water through the cation system and 100 percent through the anion system followed by disinfection, storage, and high-service pumping. Additional treatment with caustic soda for pH adjustment, and for stabilization and corrosion control, is provided; however, minimal usage is required.

The ion exchange regenerate waste from the regeneration cycles is stored in tanks and slowly pumped to the wastewater collection system at a rate of approximately 50 gal per min (gpm). Recent testing shows that the impact on the wastewater system has not been significant and agriculture reuse customers have not been negatively impacted. Conductivity monitoring at the WWTP has indicated that the concentration of total dissolved solids (TDS) after a regeneration cycle ranges between 200 mg/l to 500 mg/L, which is similar to what was anticipated. A review of the groundwater monitoring results for the reuse areas for the past year also shows no significant increases in sodium or chloride in the groundwater. The City will continue to monitor the wastewater and groundwater quality as production from the WTP increases.