WORLD SALT SYMPOSIUM

June 19-21, 2018 Park City UT, USA

Enhancing the Efficiency of Water Softener Regenerants

(WSS-18-066)

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http://www.eaglewaterquality.com/fr/hard-water/eagle-water-treatment-hard-water-2/

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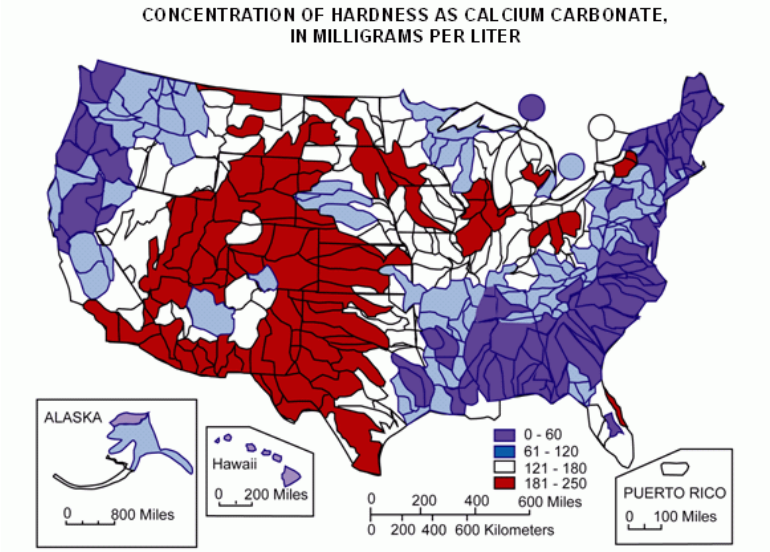
What is Hard Water?

- Water's hardness is determined by the concentration of multivalent cations in the water. Commonly found cations in hard water are calcium and magnesium.
- These ions enter a water supply by leaching from minerals within an aquifer.



https://water.usgs.gov/owq/hardness-alkalinity.html#hardness

Degree of Hardness	Grains per Gallon (gpg)	ppm (or mg/L)
Soft	<1.0	<17.0
Slightly Hard	1.0-3.5	17.1-60
Moderately Hard	3.5-7.0	60-120
Hard	7.0-10.5	120-180
Very Hard	>10.5	>180

https://www.wqa.org/learn-about-water/perceptible-issues/scale-deposits

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Impact of Hard Water?

- In household and industrial water, calcium and magnesium ions bind with available carbonate ions to form insoluble calcium carbonate and magnesium carbonate which manifest as scale on water handling equipment.

https://www.cleanwaterstore.com/blog/checking-your-pipes-for-corrosion-and-scale-build-up/

- Hard water promotes a rapid buildup of scale on water handling equipment and thus reduces the usable lifetime of such equipment.
- To mitigate the impact, water softening devices are used to remove the calcium and magnesium ions from the source water.

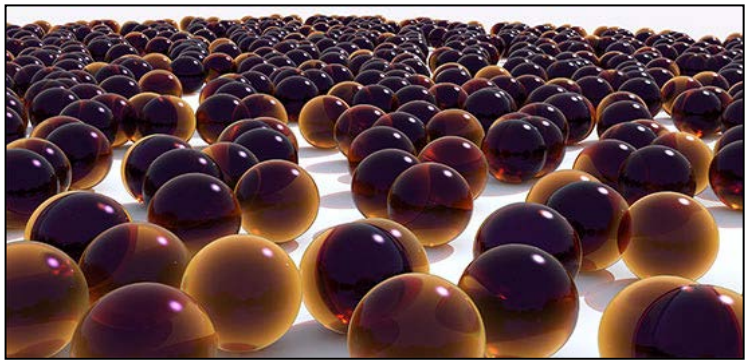
How are Hard Ions Removed?

Three Commonly Used Techniques

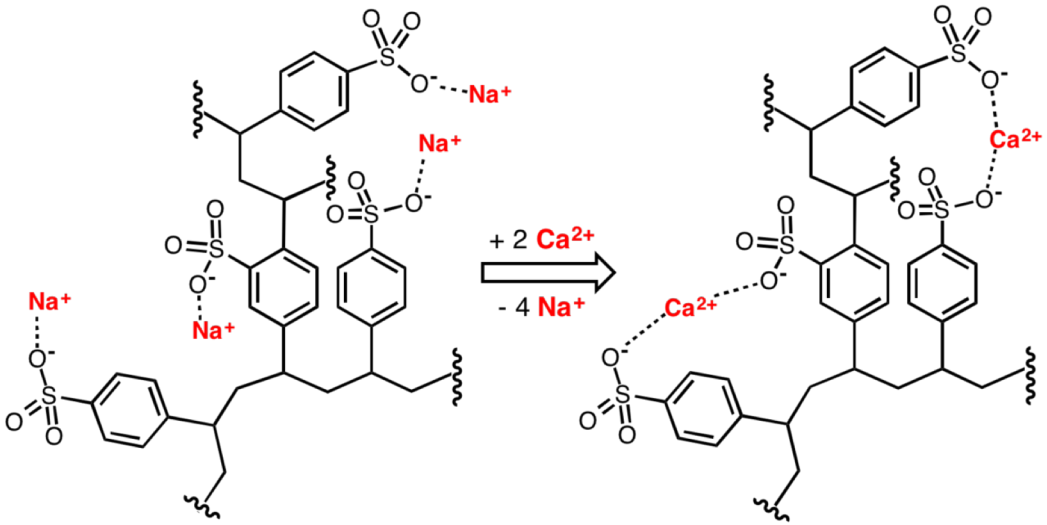
- Cation-Exchange
  - Hard ions are exchanged with sodium ions using ion exchange resins.
- Lime Softening
  - Hard ions are precipitated as insoluble minerals by using lime to alter the pH of the water.
- Reverse Osmosis
  - A reverse osmosis procedure is used to purify the water of impurities including the troublesome hard water impurities, calcium and magnesium carbonate.

How Does Cation-Exchange Work?

- Polymeric organic substrate resin that has an affinity for cations is charged with sodium ions.
- Hard water passes through the resin. The calcium and magnesium ions attach to the resin and displace the sodium ions into the water.



https://www.lanews.org/ion-exchange-resins-market-dynamics-forecast-analysis-and-supply-demand-2016-2024/



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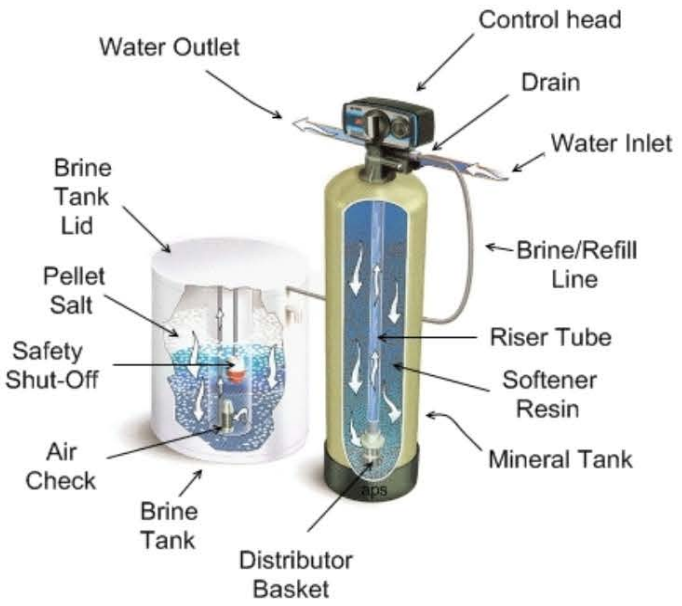
Disadvantage of Cation-Exchange

- After the resin becomes saturated with calcium and magnesium ions it must be regenerated with sodium by using a salt brine rinse.
- The regeneration water is ultimately discharged into sewer systems. This may create salinity or chlorine issues at wastewater treatment facilities.



https://www.apswater.com/article/189/Water-Softener-Diagram

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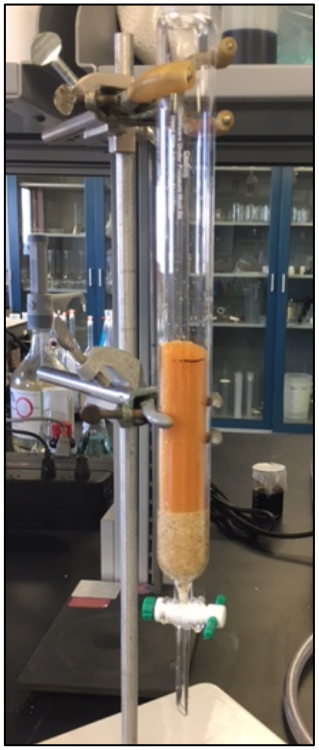
Increasing the Efficiency of Salt in the Resin Regeneration Process

Experimental Design



Bench Top Softener

Water Softener with Clear Brine Tanks

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Small Scale Study

SAMPLE	Ca^{2+} Expected (ppm)	Ca^{2+} in Effluent (ppm)	DIFFERENCE (%)
NaCl (100 mL brine)	3,716	3,716	-
NaCl (50 mL brine) + 100 ppm Polymer A	1,858	2,370	+27.6
100 ppm Polymer A (No NaCl brine)	0	2.2	0

- When polyacrylic acid (PAA) is added with sodium chloride brine the exchange reaction resulted in an increase in the amount of the calcium ions removed.
- When PAA is used without sodium chloride almost zero calcium ions were removed.

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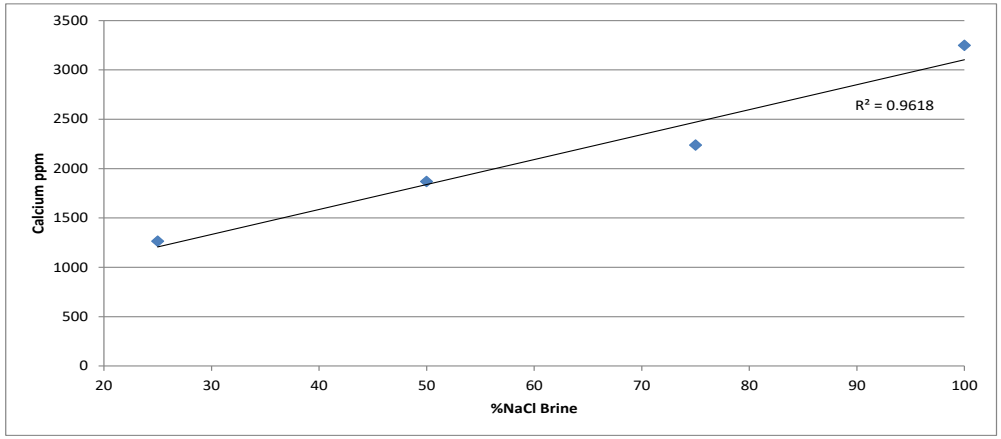
Water Softener Calibration with Different Brine Strengths

Brine Dilution	Ca^{2+} in Effluent	Impact on Efficiency
Undiluted Brine	3,248	-
75% Brine	2,238	31% Decrease
50% Brine	1,869	42% Decrease
25% Brine	1,263	61% Decrease

Calcium Removal to Brine Concentration



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Effects of Different Polymers on Calcium Removal Efficiency

Brine Dilution	Calcium (ppm) in Effluent	Efficiency Increase (%)
Brine diluted to 25%*	1263	-
Brine diluted to 25% + 500 ppm PAA	2126	68
Brine diluted to 25% + 50 ppm PAA	2164	71
Brine diluted to 25% + 25 ppm PAA	2614	106
Brine diluted to 25% + 10 ppm PAA	2324	84
Brine diluted to 25% + 25 ppm VersaFlex One	2608	106
Brine diluted to 25% + 25 ppm Versa TL3	2925	132

* *1 part brine to 3 parts water*

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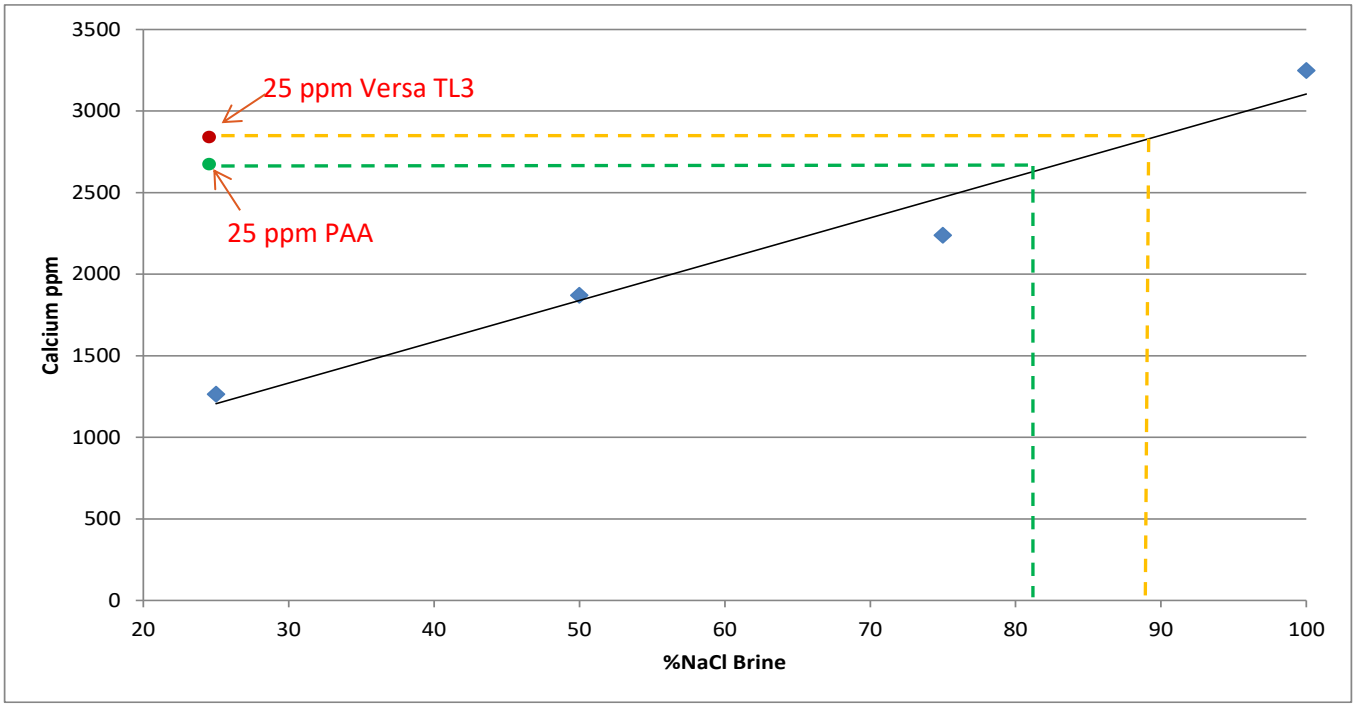
Calcium Removal to Brine Concentration



25 ppm of polymer added to the regeneration brine more than tripled the regeneration efficiency as compared to straight brine

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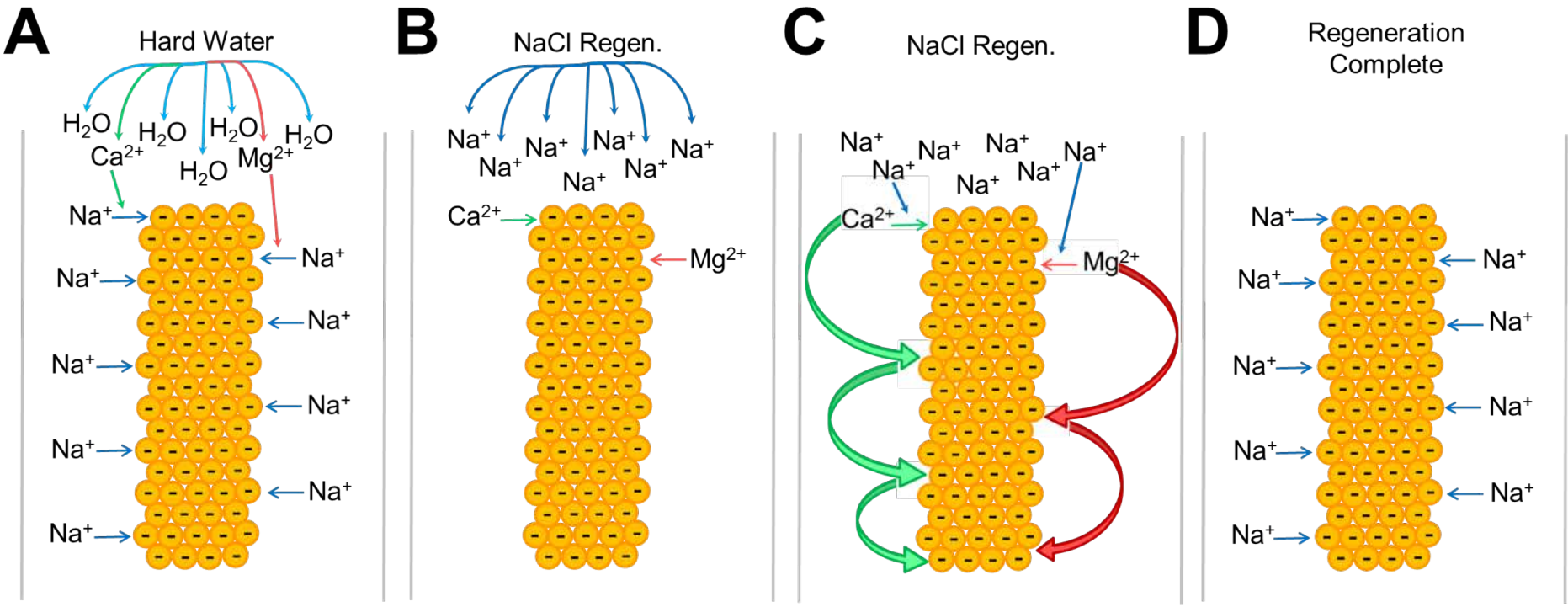
Mechanism Hypothesis

Regeneration of the Resin with Brine



Divalent ions detach from the resin and reattach multiple times, thus requiring copious amounts of sodium ions to regenerate the resin

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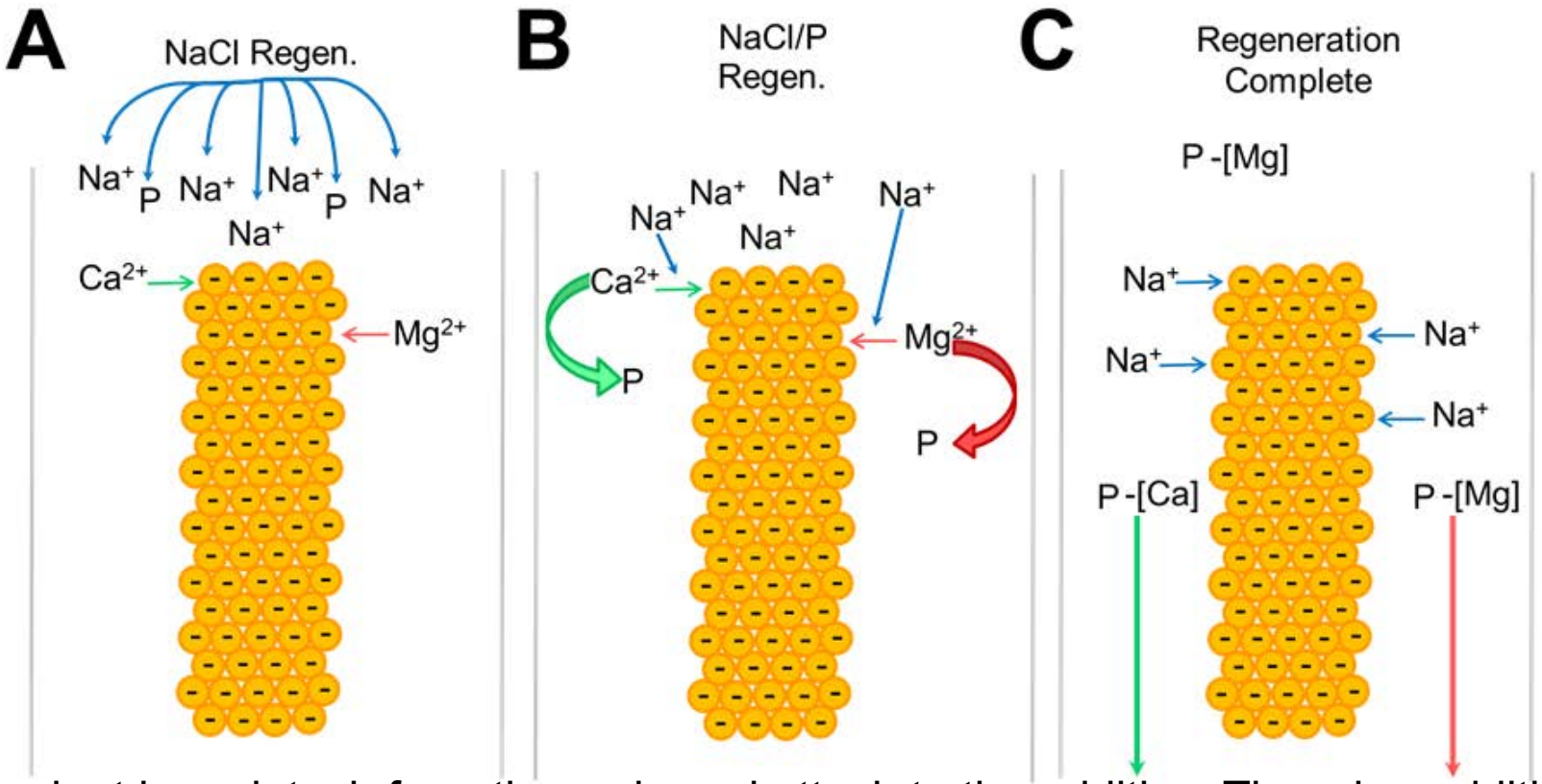
Mechanism Hypothesis

Regeneration of the Resin with Brine Plus Polymer Additive (P)



Divalent ions detach from the resin and attach to the additive. Then, ion-additive complexes are carried through the rinse without reattaching to the resin

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Conclusions

- A novel approach was discovered for increasing the efficiency of sodium chloride in cation-exchange regenerations.
- An efficiency increase greater than 3x was achieved using ppm levels of anionic polymers with sodium chloride.
- The enhanced efficiency has the potential to reduce salinity in from water softener regeneration discharge into waste water systems by 60 to 70%.

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Questions?

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