Potassium chloride as an alternate regenerant

What to know if you're considering switching a customer from NaCl to KCl.

By Frank DeSilva

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Ion exchange softening units are traditionally regenerated with sodium chloride (NaCl) brine. Sodium chloride is in abundant supply, is relatively inexpensive, and has been used as the primary source of regenerant brine for decades.

Other sodium salts have been investigated for use as a regenerant brine but have proven to be impractical because they cannot be made into a strong enough concentration to provide the necessary driving force to regenerate the softener resin. These other salts include sodium bicarbonate (baking soda), sodium carbonate (soda ash), and sodium sulfate.

An alternative salt to consider is potassium chloride (KCl), also called muriate of potash. It is commercially available, albeit in a limited supply and at a higher cost, and readily dissolves in water.

Factors that may influence the switch from NaCl to KCl include:

- Health considerations and perceptions
- Brine waste disposal
- Economics and availability.

From ion combination to 'all sodium'

The before/after water softening analysis below uses the example of water with 8.77 grains per gallon of hardness and 100 parts per million (ppm) of sodium.

Raw Water	**ppm as $CaCO_3$**
Calcium	100
Magnesium	50
Sodium	100
TOTAL CATIONS	250
Softened Water	
Calcium	<1
Magnesium	<1
Sodium	250
TOTAL CATIONS	250

Water softeners remove calcium and magnesium hardness ions by ion exchange onto a strong acid cation resin. The calcium or magnesium ions are attracted to the exchange sites on the resin. At the start of the service cycle, the resin has sodium (or potassium) ions occupying the exchange sites. The sodium (or potassium) ion is replaced by the hardness ions entering the unit. This process continues until the resin is exhausted and taken off line for regeneration.

A water softener does not reduce the total dissolved solids (TDS) level of the water. The TDS essentially stays the same, but the cation makeup of the TDS changes. The table on this page shows an example of one cation water analysis before and after softening. The softening process, which in this case is being run in the sodium form, changes the cation chemistry from a mix of calcium, magnesium and sodium to an "all-sodium" water.

From the table, it's clear that the sodium level coming out of a sodium-cycle softener is indeed elevated. The sodium level will equal the sum of the influent hardness level and the influent sodium level.

Health and 'no sodium'

People who must adhere to a low-sodium diet might be concerned about the levels of sodium in softened water. In the overall scheme of things, it may not be a valid concern given the small amount of total sodium contributed to the daily diet by drinking softened water (table, next page), but the customer's perception is paramount, and if the customer prefers a low-sodium water, then a potassium cycle softener unit is the answer.

Another positive health aspect of using KCl as the regenerant for a softener is that drinking the softened water will contribute

potassium to the diet, which is commonly deficient in daily consumption.

Potassium chloride has a higher molecular weight than sodium chloride, 74.55 versus 58.43 respectively. It would seem on this basis alone that KCl softener regeneration would require 28 percent more KCl by weight than NaCl. A potassium products producer, PotashCorp of Saskatoon, Saskatchewan, funded research studies to investigate this issue. These studies looked at the performance of identical household water softeners, some regenerated with potassium chloride and some regenerated with sodium chloride.

Sources of Dietary Sodium

Initial Water Hardness (gpg) (without sodium)	Sodium per 3 qt. Softened Water (mg.)	Sodium from Food (mg.)	Total Sodium Consumed (mg.)	% of Total from Softened Water
1	23	5000	5023	0.4%
5	112	5000	5112	2.2%
10	223	5000	5223	4.3%
15	335	5000	5335	6.5%
20	447	5000	5447	8.2%
30	670	5000	5670	12.5%
40	893	5000	5893	15.2%

Source: Water Quality Association, "Sources of Dietary Sodium," 2008

Comparing operational uses

The testing was performed at three regeneration levels: salt dosages of 4, 8, and 15 pounds per cubic foot (lb./ft.^{3}). The efficiency differences between the two salts were observed to be less than what was predicted by calculation.

The KCl regenerated softeners achieved a hardness reduction capacity from 14.6 to 32.6 kilograins per cubic foot (kgrs/cu.ft.) The NaCl regenerated softeners achieved capacities of 16.5 to 33.3 kgrs/cu.ft. In summary, the KCl regenerated softeners performed at a level of 88.7 percent to 99 percent of that obtained with an equal weight of NaCl. To achieve the exact equivalent capacity of an NaCl softener, the weight of KCl used would need to be increased by 13 percent at the 4 lb./ft.^{3} dosage level, but by only 2 percent at the 15 lb./ft.^{3} level.

The results of this report were presented at the 1991 WQA Convention and Exposition. Mentioned in the report as an "interesting result" was the fact that the KCl-regenerated units, when dosed with brine at a calculated level equivalent to the NaCl dose, discharged less chloride to waste versus the NaCl-regenerated units, between 11.4 percent and 20.8 percent less. In light of the brine discharge concerns that are currently in the news, this could be a bit of good news and is worthy of future tests.

A softener manufacturer has published information on several Web sites that shows virtually identical results for NaCl-regenerated softeners and KCl-regenerated softeners when treating a 13-grains-per-gallon (gpg) hardness water. No particulars are given on the actual salt dosages used, but in the previously mentioned PotashCorp study, the efficiency differences at the higher end of the dosage scale were only 2 percent, so it is likely that this testing used dosages in this range.

Additional comments from the same softener manufacturer were that the customers noticed no discernable difference between taste or feel of the NaCl- or KCl-softened waters.

Some softeners have controllers with different settings for NaCl or KCl brine regeneration. Others recommend increasing the grains of hardness setting in the controller by 20 percent to accommodate the need for slightly additional amounts of potassium chloride regenerant.

Practical considerations

- *Physical parameters:* Potassium chloride is normally supplied in the granulated form. It is more prone to caking and salt bridging than NaCl. Also, the solubility of KCl fluctuates with temperature to a greater degree than NaCl, and so may not be as suitable for applications which have brine tanks located outdoors.
- *Brine discharge:* Potassium is a more environmentally acceptable cation than sodium. It is an essential mineral for plants and is a more compatible salt for discharge into a septic tank and drainfield. Diluted potassium brine discharge may be recyclable for some irrigation applications.
- *Supply and cost:* Potassium chloride is getting to be more expensive, and supplies are limited, at least for the near future. Currently, there is a strong global demand for potash fertilizer, a result of worldwide economic growth, increasing demand for food, and a subsequent need for more fertilizer for crops. Also, crop-based fuel sources such as ethanol and biofuels require fertilizer.

Approximately 95 percent of all the potash that is made is used by agriculture. Fertilizer consumption worldwide grew by 26 percent from 2006 to 2007. Fertilizer use is projected to grow approximately 35 percent from 2007 to 2008. Potash fertilizer is the raw ingredient for making potassium chloride pellets. The current demand for this chemical has driven up prices, resulting in a short supply and increased costs for potassium chloride.

To sum up, potassium chloride is a viable alternative to sodium chloride for regeneration of water softeners when the application requires a low-sodium softened water or a low-sodium waste brine, and also when the additional cost is justified. **WT**

References and Sources

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