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It's All In Your Water

Water Softening (Ion Exchange)

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Most water delivered to homes from wells, rural water or municipal sources contains some "hardness." Hard water can be a nuisance, thus the need for water softeners. Standard water softeners found in home supply and hardware stores will remove nearly all the hardness from water. Some softeners will also remove up to 10 ppm of iron and manganese. Water supplies with high levels of iron and manganese (greater than 10 ppm) may need a dedicated iron removal system.

What makes water "hard"?

Hard water is defined as the combined amount of dissolved calcium, magnesium and iron present in the raw water. Typically, the concentration of iron is very small compared to the concentration of calcium and magnesium. As water passes through soil, rocks and minerals, it dissolves some calcium and magnesium ions. These dissolved ions give hard water its characteristics.

How is hardness measured?

In water test reports, the hardness measurement can be listed in grains per gallon (gpg), parts per million (ppm) and sometimes as milligrams per liter (mg/l). In water, one ppm is generally considered equal to one mg/l. One gpg is equal to 17 ppm or 17 mg/l. **Table 1** shows how hardness is classified. According to NSF International, the Public Health and Safety Company, consumers believe they have a problem when hardness surpasses the 6 to 7 grain per gallon level.

Table 1. Hardness Classification (hardness as calcium carbonate).

	Mg/l or ppm	Grains per Gallon (gpg)
Soft	Less than 17	Below 1.0
Slightly hard	17-60	1.0 to 3.5
Moderately hard	61-120	3.5 to 7.0
Hard	121-180	7.0 to 10.5
Very hard	More than	Above 10.5

Problems caused by hard water

A whitish buildup on the ends of faucets and shower heads is probably the most obvious result of hard water. But hard water also decreases the cleaning ability of detergents used in clothes and dish washing machines. Problems arise when cleaning agents do not fully remove dirt and grime. Over time, clothes washed in hard water may look dingy and feel harsh and scratchy. White clothing continually washed in hard water will gradually show a grayish tinge. Dishes and glassware washed in dishwashers using hard water may be spotted when dry. Hard water causes films on glass shower doors, walls and bathtubs. Hair washed in hard water may feel sticky and look dull. After showering in hard water, skin will feel rough and scratchy. It is especially noticeable in the winter when the relative humidity of the air is low. Another problem is a scum buildup that occurs when soap

combines with dissolved calcium and magnesium. Soap scum is difficult to remove from sinks and appliances.

Household appliance performance may be affected by hard water. When heated, calcium carbonate and magnesium carbonate precipitate from the water and coat the heating elements in electric hot water heaters. In addition, the precipitate will also coat the inside of the tanks for both electric and natural gas hot water heaters. A large-scale buildup slows the heating process and requires more energy to heat water. Water heaters with large accumulations of mineral buildup will have shorter life spans. Scale deposits also accumulate to plug plumbing fixtures and build up in other appliances like coffee pots.

The ion exchange process

The dissolved calcium (Ca^2+) and magnesium (Mg^2+) ions that cause hard water can be removed fairly easily by using an ion exchange procedure where the relatively large calcium and magnesium ions displace smaller sodium (Na+) ions. Standard water softeners are classified as cation exchange devices where the term cation refers to positively charged ions dissolved in water. In the ion exchange process, the smaller sodium ions are used to coat an exchange medium in the softener. The exchange medium can be natural "zeolites" or synthetic resin beads that resemble wet sand.

As hard water passes through a softener, the calcium and magnesium ions trade places with sodium ions **(Figure 1)**. Sodium ions are held loosely and are easily replaced by the larger calcium and magnesium ions. During this process "free" sodium ions are released into the water.

Softening Process

After a certain amount of hard water has passed through the softener, much of the exchange medium becomes coated with calcium and magnesium ions. When this occurs, the exchange medium must be recharged or regenerated **(Figure 1)**. To recharge the softener with sodium ions, a softener is backflushed with a salt brine solution. Sodium ions are supplied from the dissolved sodium chloride (NaCl) salt brine. During a backflush operation, sodium ions in the brine solution replace the calcium and magnesium ions on the exchange medium.

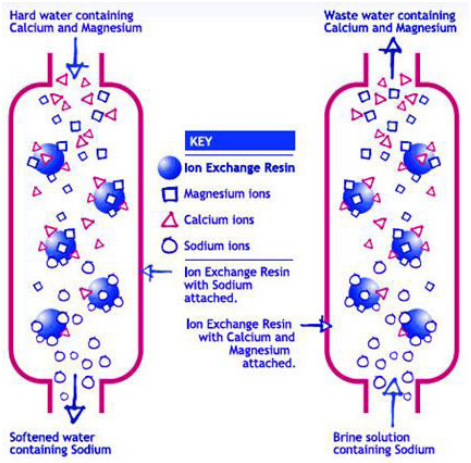

Figure 1. Softening process.
(Adapted by D. Baer, 2012.)

Recharging Process

The time between recharging cycles depends on the hardness of the water, the amount of water used, the rated hardness removal of the softener and the capacity of the exchange media to remove hardness.

Have Your Water Tested

Before buying any water treatment equipment, you should know what impurities are in the water supply. The types and amounts of impurities in your water can be determined by an accredited water testing laboratory. A list of water testing laboratories is available in NDSU WQ1341 *"Drinking Water Quality: Testing and Interpreting Your Results."* The results of the water test will help determine if softening is needed. The water test may reveal other dissolved minerals that may require additional treatment.

If you obtain water from a private water supply, water testing is your responsibility. Water testing should be done on a regular basis. If a problem is suspected, test more often.

Community water supplies are monitored and treated to protect users from health threatening water impurities but may still have high hardness. Ask your supplier for a copy of the latest water test results.

Consumption of hard water is actually good for humans since the body will use some of the calcium and magnesium, but for appliances, it is considered a nuisance and not a health problem. Hardness removal is not a necessity to protect your health, but water softening is popular because most people prefer softened water for bathing, cleaning and washing.

Health risks associated with softened water

During the softening process sodium is released from the exchange media into the output water. For every grain of hardness removed from water, about 8 mg/1 (ppm) of sodium is added. People on restricted-sodium-intake diets should account for increased levels of sodium in softened water. Your family physician should be consulted. Sodium intake from softened water can be avoided by leaving one kitchen tap unsoftened for drinking and cooking. Substituting potassium chloride for sodium chloride may be appropriate if health or environmental reasons necessitate restricting sodium. Potassium chloride is more expensive and adheres more strongly to the resin, reducing the exchange efficiency when compared to sodium chloride. About 10% more potassium chloride salt is used during the backflush operation.

Types of water softening equipment available

The primary difference between water softener models is in the way they schedule the backflush cycles. This is important because recharging the beads with salt too early wastes salt and water. Recharging too late causes performance to fall off.

Water softeners are classified into four different categories:

1. **Semiautomatic:** The operator initiates only the recharging cycle. A button is pushed when the softener needs recharging and the unit will control and complete the recharging process.
2. **Automatic:** The most common softener is equipped with a programmable timer that automatically initiates the recharge cycle operation. The operator needs only to set the timer and add salt when needed. However, many models allow the homeowner to either use the timer or set the recharge cycle based on amount of water that has passed through the softener.
3. **Demand-initiated regeneration (DIR):** All operations are initiated and performed automatically in response to the water use demand for softened water. DIR systems generally have two softening tanks and a brine tank. While one tank is softening the other tank is recharging.
4. **Off-site regeneration (generally rental units):** A used softening tank is physically replaced with a recharged tank. Spent softening tanks are then recharged at a central location.

Operation and maintenance

Maintenance of water softeners is largely confined to restocking the salt supply for the brine solution. With semiautomatic models, the owner will also have to start the recharging cycle. Salt can be purchased in the form of pellets, granules or blocks.

The brine tank may require periodic cleaning. The operator's manual will usually have instructions on how to use bleach to clean the brine tank. The frequency of cleaning depends on the amount and purity of the salt used in the softening process. The brine valve and float assembly should also be checked and cleaned as often as needed.

The presence of excess iron or hydrogen sulfide can inhibit the effectiveness of a water softening unit. Installation of the iron removal equipment may be required (see the NDSU *"Iron and Manganese Removal"* publication WQ1030). Water test results will help make that determination. More frequent backflushing (reversing the normal flow of water through the treatment unit) may be required to remove iron buildup.

Cost of water softeners and supplies

Retail prices for home water softeners may range from approximately $400 to $2,700 depending on the size and type of softener. Softeners are rated by the total number of grains the unit can remove before being recharged. Cost of salt is approximately $5 to $10 per 40-pound bag of sodium chloride (NaCl) depending on the form purchased and up to $25 per 40-pound bag for potassium chloride (KCl).

Advantages of water softeners

Softeners offer: 1) cleaner, softer-feeling clothes; 2) longer life of appliances including washing machine, dishwasher and water heater; 3) less use of household cleaning products, such as detergents, as well as personal cleanliness products, like shampoo; 4) reduction of water spotting.

Disadvantages of water softeners

1) Softened water is not recommended for watering house plants, lawns and gardens due to its sodium content. 2) Water used in recharging a water softener may overload or reduce the effectiveness of small septic or sewer systems. 3) There may be health risks from sodium intake. 4) Softened water is not recommended for steam irons or evaporative coolers. The best choice for such appliances is distilled water or water from a reverse osmosis unit.

Alternatives to ion exchange units

Hard water problems can be reduced by using detergents that include water softening chemicals in their formulation. Some types of chemicals can be added to hard water to reduce the negative effect from calcium and magnesium. Chemical treatment for household water softening is recommended for low levels of hardness.

Two types of chemicals used to soften water for home laundry are Sal Soda and Calgon.

Sal Soda combines with calcium and magnesium to form solid particles. These particles settle out with particles of dirt during washing. Use of precipitating additives such as Sal Soda may not fully clean your laundry because solid particles may cling to fabrics.

Calgon softens water by combining with calcium and magnesium to form compounds that stay in solution. Use of nonprecipitating additives such as Calgon has a negative environmental effect because they have high phosphate content.

Magnetic conditioning

Magnetic water conditioning devices have been marketed based on a variety of claims regarding their effect on water hardness and related scale formation. The Water Quality Association, a not-for-profit trade association for the water treatment industry, has not been able to determine standards for these products and report inconsistent performance to date. Several research reports have stated that there was no change in the physical and chemical properties or the calcium ion concentration of water treated with these devices.

Items to consider when purchasing an ion exchange water softener

- Test your water to determine the hardness and other impurities that may need to be removed.
- Determine how much softened water your household needs per day, per year.
- What type and size of softener will fit your situation?
- How easy is the softener to clean and/or repair?
- Will the dealer provide service?
- What type of convenience level should a softener offer (manual or automatic operation)?
- Will pretreatment be needed for iron and manganese?
- Will sodium intake be a health problem?
- Will sodium salts overload your septic or sewer system?
- Investigate equipment before purchasing or renting. Don't rush a purchase.
- Purchase price does not directly indicate a softener's performance. A moderately priced unit might work as well as an expensive unit.
- When buying or renting, are the installation costs included in the price?
- Don't buy more equipment than you need. Other removal systems might be better suited for the removal of certain impurities.
- Choose a reputable dealer. Get guarantees in writing and read them thoroughly.
- Beware of manufacturer's advertising that is too good to be true.
- Equipment should have a stamp from one of these water testing organizations: Underwriters Laboratory (UL), NSF International or Water Quality Association.

References

G1491 Drinking Water Treatment: Water Softening (Ion Exchange) University of Nebraska, Lincoln http://www.ianrpubs.unl.edu/epublic/live/g1491/build/g1491.pdf

MWPS-14 Private Water Systems. MWPS at Iowa State University (https://www.mwps.iastate.edu)

Further Information

For further information contact your local county extension office or state health department. Additional information can be found in other publications in this series:

- WQ1029 Filtration: Sediment, Activated Carbon and Mixed Media
- WQ1030 Iron and Manganese Removal
- WQ1341 Drinking Water Quality: Testing and Interpreting Your Results
- WQ1352 What's Wrong With My Water? Choosing the Right Test

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