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*Agricultural and Biological Engineering*

# Water Softening

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**Paul D. Robillard, Associate Professor, Agricultural Engineering**
**William E. Sharpe, Professor, Foreest Hydrology**
**Bryan R. Swistock, Extension Associate**

Soft water and hard water are common terms used in households across Pennsylvania. If you asked someone what these terms meant, you would probably get a definition based on how well the water cleans when used with detergents or soaps or what is left behind in tea kettles. For example, "hard water is what causes the white scale buildup on my pots," or "soft water doesn't leave a detergent film on my fresh-washed clothes or fixtures." Some might even contend that soft water makes their skin smoother and hair more silky and manageable. While these observations may be true, they may not be substantial reasons to purchase a water softening device. *It is also important to note that water softeners will not necessarily remove any of the more serious drinking water contamination problems*. An understanding of the chemistry of hard and soft water and the treatment process used to produce softer water can help you answer the question, "Do I need to soften my water?"

## Hard Water/Soft Water

Whether a water supply is labelled "soft" or "hard" is dependent on the presence of two highly soluble minerals, calcium and magnesium. *From a health standpoint, these minerals have no adverse effects and are, in fact, essential daily nutrients.* It is minerals that give water the refreshing flavor many people find desirable. However, when calcium and magnesium permeate water, they buildup on contact surfaces, possibly plug pipes and damage water heaters, and decrease the effectiveness of soaps and detergents. At this point the water is said to be hard.

Water hardness is expressed in one of two units of measurement. The first unit is parts per million (ppm) of calcium carbonate, a term equivalent to the concentration of dissolved calcium and magnesium. Using this equivalent simplifies hardness calculations. One ppm means that one unit of calcium carbonate is dissolved in one million units of water. Parts per million is also equal to milligrams/liter (mg/l). A second expression of hardness is grains per gallon (gpg) of calcium carbonate. A gpg is used exclusively as a hardness unit and equals approximately 17 mg/l or ppm.

If you have your water tested, the report will use one or both of these units to tell you how hard your water is. Since the level of calcium carbonate means little to water consumers, water specialists have classified levels of hardness. Table 1 shows these classifications.

*Table 1. Water Hardness Classification.*

| Classification | Grains per gallon (gpg) | Parts per million or milligrams per liter (ppm) or mg/l) |
|---|---|---|
| Soft | Less than 1.0 | Less than 17 |
| Slightly hard | 1.0 to 3.5 | 17 to 60 |
| Moderately hard | 3.5 to 7.0 | 60 to 120 |
| Hard | 7.0 to 10.5 | 120 to 180 |
| Very hard | Greater than 10.5 | Greater than 180 |

## The Water Softening Process

Once water hardness is known, you have two options. *You can live with the hardness level*, recognizing that levels below 7.0 gpg will probably not cause major scaling and soap film, *or treat the water to reduce the calcium and magnesium present.* A water softener, also called an ion exchange unit, will effectively accomplish the latter option.

*Ion Exchange.* Because water softening devices have long been available in the water treatment industry, the technology is highly developed and in most cases works well to reduce the hardness level. How does ion exchange work? A physical and chemical process filters the water through an exchange media known as resin or zeolite. Typically, the resin is

a synthetic or natural, sand-like material coated with positively charged sodium ions. As the calcium and magnesium dissolves into positively charged ions, an ion exchange environment is created. The water flows through the unit while the resin releases its sodium ions and readily trades them for the calcium and magnesium ions. The water flowing out of the device is now considered soft.

*Regeneration.* Clearly the resin is not an inexhaustible exchange site. When all the sodium exchange sites are replaced with hardness minerals, the resin is spent and will no longer soften water. At this point, the water softener will need to be run on an alternate cycle called regeneration. During this cycle, resin is backwashed with a salt solution. The brine is reverse flushed through the system taking with it the calcium and magnesium ions that had been adsorbed on the resin. Once backwashing is complete, the softener can be returned to use. Some water softeners will automatically switch to the operation cycle. Others have a manual switch. Figure 1 illustrates both cycles of the water softening process—ion exchange and regeneration.

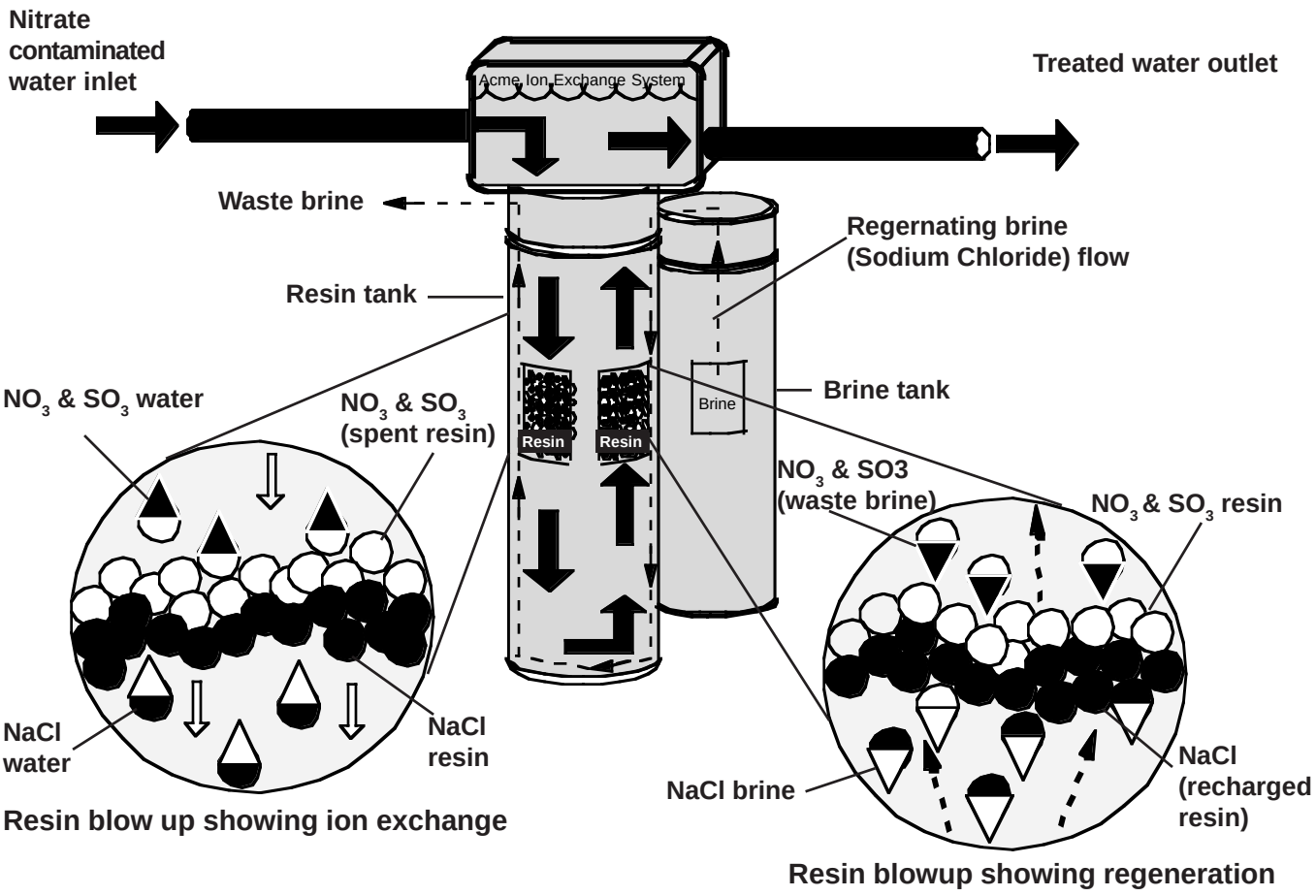


**Figure 1. A typical water softener showing ion exchange and regeneration.**

*Kinds of softeners.* Although many brands and models of ion exchange units exist on the market, all essentially perform the same with minor differences in extra features, flow rates, etc. Nearly all softeners fall into one of two categories. Timed models have programmable timeclocks that will regenerate on a predetermined schedule and then return to service. These work well for households that are on regular water-using cycles but will waste more water and salt because they regenerate whether the resin needs it or not. Demand-control models, with either electrical and mechanical sensors, usually regenerate after so many gallons of water have been softened. Such models are convenient if you have a fluctuating water use schedule.

*Maintenance.* No matter which model you choose, all water softeners need to be properly maintained. The brine solution must be mixed and stored in the brine tank. Periodic clogging of the resin also requires

special attention. For example, if the raw water supply is turbid it may clog the resin with mud and clay. Sometimes, normal backwashing with water will solve this problem. If not, slowly stir the resin during the backwash cycle to help break up the material. Likewise, bacteria and fungi also form mats in the resin that reduce its effectiveness. Disinfecting the water prior to softening or periodically cleaning the softener with chlorine bleach will eliminate these nuisances. However, read the manufacturer's instructions before adding any chemicals to the unit.

Iron fouling is another common maintenance problem for water softeners. Although colorless, reduced iron will be removed by the unit, red-oxidized iron (iron that has been exposed to air or chlorine) will clog the resin. Filtration prior to softening insures that oxidized iron is not processed in the softener. If the resin has already been fouled, commercial cleaners are available. Again, it is advisable to check the manufacturer's instructions for special precautions.

In some instances, resins can not be washed of contaminants and will need to be replaced. (This should *not* be the case if the resin is periodically regenerated and maintained.) Consult your water softener dealer for information on resin replacement.

*Costs.* Water softening costs depend on factors such as installation, maintenance fees, and size of the unit. You can also expect that with more convenience features, the price of the unit will increase. An average range for the hardware only is around $500-$1500.

## Advantages and Disadvantages of Water Softening

*As the water treatment industry has grown in the U.S., the concept of water softening has often been misconstrued as a purifying, cleansing or conditioning process*. This is due largely to exaggerated advertising and, in part, to consumer misconceptions about water treatment. But the reality is that water softening simply removes hardness minerals and eliminates problems that are a nuisance and not a threat to human health. The decision "to soften or not to soften" is a matter of personal preference not necessity. However, water softening does have advantages, and disadvantages, that make this decision a significant one.

*Advantages*. Most consumers would agree that hard water leaves scales on pots, soap films on skin, and detergent curds in the washing machine. More importantly, scales can also buildup on hot water heaters and decrease their useful life. Soap film and detergent curds in bathtubs and appliances indicate that you are not getting the maximum cleaning action from these products. Soft water not only eliminates these nuisances but also protects appliances and saves cleaning time.

There are other advantages to water softening, as well. It is a well developed technology that has been used in homes for almost 65 years. The equipment is reliable, effective, and widely available, providing consumers with convenient features and a selective market. The simple technology of softening makes it easy to bypass toilets and outdoor faucets. Finally softening systems are adaptable for mixing softened and unsoftened water to produce a lower hardness level.

*Disadvantages.* The major disadvantage to water softening is the potential health risks for people on low sodium diets. The exchange of hardness minerals for sodium adds 7.5 milligrams per quart for each gpg of hardness removed. In addition, calcium and magnesium are eliminated from the homeowner's diet.

Maintenance is another consideration. While you can purchase models with special features that do everything but add the salt, you will pay for each additional feature. The tradeoff will be cost for convenience and you have no longterm guarantee that the special feature will not fail. Depending on the water source, you may have to filter turbid water or disinfect bacteria-laden water—all before it even reaches the softening unit. Finally, if you own a septic system, you should consider the additional load on your drainage field from backwashing and regeneration. Estimates indicate that about 50 gallons of water are used for each regeneration cycle. This may or may not cause hydraulic overload of the septic system.

## Selecting a Water Softener

If after weighing the advantages and disadvantages of water softening, you decide to soften your water, the next question you must consider is "How much?" Have the water tested *by an independent lab* and determine its classification from Table 1. Although many water softening companies offer free hardness testing, its best to have a third party evaluation. An independent lab test is not expensive and will protect you from being oversold. Next, recognize that unless your water is extremely hard, all the incoming water does not need to be softened. Showers, sinks, and laundry hookups probably should be softened; toilets, outside spigots, and basement sinks can be bypassed. In some cases, you may desire to soften the hot water only. Measure the water usage at the designated hookups for each person in the household or use the following table as a guide.

**Table 2. Guidelines for estimating water use.**

| Use | Water usage |
|---|---|
| Household drinking and cooking | 1 gal/person/day |
| Bathing and showering | 25-60 gal/use |
| Dishwashing | 6-19 gal/use |
| Clothes washing | 20-33 gal/use |

You can estimate the size of the softener you will need and the regeneration cycles using the following calculation as an example:

20,000 = Sample capacity (number of grains per regeneration)
75 gallons = average person usage per day
10 gpg = raw water hardness
4 people = household size

75 gallons (10 gpg) x 4 = 3,000 grains per day used
20,000/3,000 = about 6-7 day regeneration

**Figure 2. Sample calculation for determining a regeneration cycle.**

Finally, using this information, select a softener that meets your needs and provides the conveniences you desire. Recognize that all softeners use essentially the same process. For this reason, most softeners are not rated for effectiveness, only for convenience features like handiness, size, maintenance requirements, safety and cost. These features are a matter of personal preference. So be wary of sales people who attempt to sell you on their product's ability to outlast or "outsoften" other products. Most water softeners are hardware on which you can rely.

## Additional Resources

**For further information and resources on:**

- **Drinking Water Quality (see fact sheet F 101 *Drinking Water Publications from the Penn State College of Agricultural Sciences)***
- **Groundwater Protection**
- **Watershed Monitoring & Control Systems**

**Please access:**
**Website: http://wqext.psu.edu**
**Email: mxh16@psu.edu**
**Fax: (814) 863-1031**
**Phone: (814) 865-7685**

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