ENVIRONMENTAL Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

WD-DWGB-3-6 2008

Hardness in Drinking Water

DEFINITION OF HARDNESS

Hardness in drinking water is defined as those minerals that dissolve in water having a positive electrical charge.

The primary components of hardness are calcium (Ca^{++}) and magnesium (Mg^{++}) ions. Dissolved iron (Fe^{++}) and manganese (Mn^{++}) also satisfy the definition of hardness, but typically make up only a very small fraction of total hardness. Minerals are composed of either atoms or molecules. An atom or molecule that has dissolved in water is called an "ion." Positively charged ions are called cations and are noted as (+). A double sign would indicate a plus two electrical charge. Contaminants having a similar positive charge would be removed by a matching type of ion exchange resin, i.e. water softening.

HEALTH EFFECTS OF HARDNESS

The presence or absence of the hardness minerals in drinking water is not known to pose a health risk to users. Hardness is normally considered an aesthetic water quality factor. The presence of some dissolved mineral material in drinking water is typically what gives the water its characteristic and pleasant taste. At higher concentrations however, hardness creates the following consumer problems.

- Produces soap scum most noticeable on tubs and showers.
- Produces white mineral deposits on dishes more noticeable on clear glassware.
- Reduces the efficiency of devices that heat water. As hardness deposits build in thickness, they act like insulation, reducing the efficiency of heat transfer.

It has also been observed that areas of higher hardness in drinking water maybe associated with lower incidents of heart disease. This possible relationship is being investigated.

EXPRESSING THE AMOUNT OF HARDNESS IN WATER

There are two numbering systems used by drinking water professionals to identify the concentration of hardness in drinking water. They are:

- Milligrams per liter, abbreviated as mg/L; can also be defined as parts per million, abbreviated as ppm.
- Grains per gallon, abbreviated as gpg.

To convert from one hardness scale to the other, use the following formulas:

a. (the concentration in milligrams per liter) x $^{1}/_{17.2}$ = (the concentration in grains per gallon)
b. (the concentration in grains per gallon) x 17.2 = (the concentration in milligrams per liter)

Equivalent Concentration as $CaCO_3$
The concentration of hardness in water is normally **reported** as an equivalent concentration of calcium carbonate ($CaCO_3$). This laboratory calculation provides a common reference to identify the chemical **reactive power** of various compounds regardless of their atomic weight or valance. Thus using the typical laboratory units used for expressing hardness are "mg/L as calcium carbonate." The equivalent weights for various cations are shown below.

Contaminate Concentration	Equivalent Weight
10 mg/L Calcium	24.97 mg/L as $CaC0_3$
10 mg/L Magnesium	41.18 mg/L as $CaC0_3$

CATEGORIZING HARDNESS
Water supply professionals do not fully agree on the descriptive terminology that should be used when categorizing the concentration of hardness in water, nor what lower threshold concentration justifies the investment in a water softener. Shown below are the two common severity scales used to categorize hardness.

Categorizing Hardness

Worded Description	Sanitary Engineers (mg/L as $CaCO_3$)	Water Conditioning Industry (mg/L as $CaCO_3$)
soft water	0-75	0-50
somewhat hard water	76 to 150	51-100
hard water	151 to 300	101-150
very hard water	301 and up	151 and up

TREATMENT ALTERNATIVES FOR ADDRESSING HARDNESS
Historically, hard water has been addressed by installing a water softening treatment device. More recently other methods to address hardness have been proposed. All are discussed below.

MEMBRANE SEPARATION
Over the last few decades membrane separation treatment of water has made tremendous technical strides. Membrane technology is favored because of low capital and operational costs, small space requirements, and minimal treatment chemical needs. The most well known membrane process is reverse osmosis (RO). RO can remove the smallest dissolved impurities (ions) from water. Because hardness ions are larger, a coarser, less expensive, membrane can be used. This membrane is known as a **nanofiltration** membrane.

In membrane separation, approximately two-thirds of the water that enters the device will become **reject water**. If only seeking a few gallons of water per day the treatment efficiency is relatively unimportant. If using RO for whole house treatment, then a substantial amount of water would be "wasted" to produce a day's demand and the overall efficiency is of more interest. Thus the water supply yield of the well being treated by membrane technology must be significantly in excess of the home's pure water demand. The efficiency of RO treatment process increases with warmer water because warmer water with lower viscosity moves easier through the membrane. Thus nanofiltration is **not** normally chosen for wells with very low yield or for areas with very high energy costs.

MAGNETIC AND ELECTRONIC (M/E)
In these devices, electronic or magnetic energy is applied to the hard water by proprietary devices. This action is generally described as changing the form or characteristics of the hardness so as to prevent the scale buildup and other negative effects of the hardness.

There is controversy relative to the true effectiveness of this process. In this process the hardness is not removed from the water. As of this writing, DES does not have sufficient independent technical data to judge whether M/E treatment devices for hardness are effective. Visit the fact sheets webpage at www.des.nh.gov/organization/-

commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-2-10, “Magnetic/Electronic Water Treatment Devices,” for more information.

WATER SOFTENING

Water softening uses an ion exchange process. Sodium typically is put into the water while hardness and certain other minerals are proportionally removed. A private home water softener typically has two tanks. The taller tank contains the purifying media called a cation ion exchange resin, while the smaller tank contains the sodium or potassium salt used to regenerate the exchange resin. During normal operations, raw water passes through the ion exchange resin media in the tall tank. The calcium (Ca^{++}), magnesium (Mn^{++}), iron (Fe^{++}), or manganese (Mn^{++}) ions and other ions in the water are “exchanged” for sodium (Na^{+}) or potassium (K^{+}) ions which have been temporarily stored in the pores of the exchange resin. Visit the fact sheets webpage at www.des.nh.gov/-organization/commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-3-17, “Sodium and Chloride in Drinking Water,” for more information on sodium and chloride in drinking water and WD-DWGB-2-12, “Ion Exchange Treatment of Drinking Water,” for more information on the ion exchange process. A recent improvement in softeners is the introduction of an equipment configuration that backwashes when needed rather then by time clock.

As the softener removes hardness minerals from the water supply, sodium or potassium will be given back to the water proportionally. Shown below is the concentration of either sodium or potassium that would be **added** to the **existing** raw water concentration, if 10 mg/L of hardness is removed. To determine the increase for your situation, divide your total hardness by 10 and then multiply that result by the appropriate number to the right of the equal sign.

Hardness Removed	Na^{+} or K^{+} Added	
10 mg/L	Sodium (Na^{+}) added	= 4.6 mg/L
10 mg/L	Potassium (K^{+}) added	= 7.6 mg/L

Eventually the removal capacity of the resin media becomes exhausted and the resin will need to be regenerated. The regeneration process begins by a rapid backwashing of the resin to remove any fine particulate material that may originate in the well. The process then continues at a slower rate by “brining” which is the adding of salt solution to the resin. During this process the sodium or potassium from the brine enters the resin pores and displaces the previously removed hardness ions or iron/manganese. After approximately 20 minutes, the remaining brine, along with the concentrated displaced hardness ions and other ions are flushed out of the device and disposed of into an approved dry well, septic tank, or sewer.

Some owners of water softeners have expressed concerns relative to the affect of the waste brine on their leachfields. Studies by the Water Quality Association (WQA) indicate that concentrated waste brine and purged contaminants do not injure leach fields or septic tanks. The WQA is the professional association of the small water treatment device industry. Additional studies are now underway.

Sodium and chloride do not disappear when disposed into the ground. Sometimes this disposal can contaminant wells downhill of the party using the softener. Thus, reducing salt usage as much as possible is desirable. Visit the fact sheets webpage at www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-2-12, “Ion Exchange Treatment of Drinking Water,” for more information concerning achieving high efficiency when using water softeners.

Advantages of Water Softening

- Softener resin can be regenerated and re-used.
- Ion exchange can consistently remove hardness from water to extremely low levels.
- Softening removes **dissolved** iron and manganese (ie colorless). Other water quality factors, such as pH and alkalinity, are not critical to removing iron and manganese.
- Conventional softening can also remove other health related contaminants.

Disadvantages of Water Softening

- Adds sodium or potassium to your drinking water depending on which "salt" you use. For those concerned with elevated sodium levels in their drinking water, potassium chloride (KCl) can be substituted in place of sodium chloride (NaCl). The process is equally as efficient, however the cost of potassium chloride is higher than sodium chloride.

- Softening will not operate satisfactorily if particulates such as iron bacteria, clay particles, rusty colored water exists, even occasionally. If any solids are present, a particle (sediment) filter must be installed before the media tank.

- Water softeners require a location to dispose of waste brine. If you do not have sewer service, disposal of the waste brine will likely be into the ground. This creates the potential of contaminating the groundwater, and subsequently your own well or those wells of your neighbors down hill. When potassium chloride is used, the potassium should be recognized as a soil nutrient, being one of the three components of typical manmade fertilizer.

REDUCTION OF SALT USAGE

Waste brine typically can contaminate the general groundwater in your neighborhood and possibly that of your own well. Consequently, reducing salt usage while maintaining water system treatment effectiveness is important. Methods of reducing salt usage are listed below. Visit the fact sheets webpage at www.des.nh.gov/organization/-commissioner/pip/factsheets/dwgb/index.htm and scroll to WD-DWGB-2-12, "Ion Exchange Treatment of Drinking Water," for full discussion of all of these salt saving concepts.

1. **Demand based** initiation of the regeneration. Device only backwashes when the existing softening capability has been fully used up.
2. Low concentration salt regeneration: **6-8 pounds of salt/ft^3** of media versus **10-12 pounds/ft^3**.
3. Partial reuse of waste brine by capturing the last1/3 of brine waste from the previous regeneration cycle.

FOR MORE INFORMATION

Please contact the Drinking Water and Groundwater Bureau at (603) 271-2513 or dwgbinfo@des.nh.gov or visit our website at www.des.nh.gov/organization/divisions/water/dwgb/index.htm. All of the bureau's fact sheets are on-line at www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm.

Note: This fact sheet is accurate as of October 2008. Statutory or regulatory changes or the availability of additional information after this date may render this information inaccurate or incomplete."