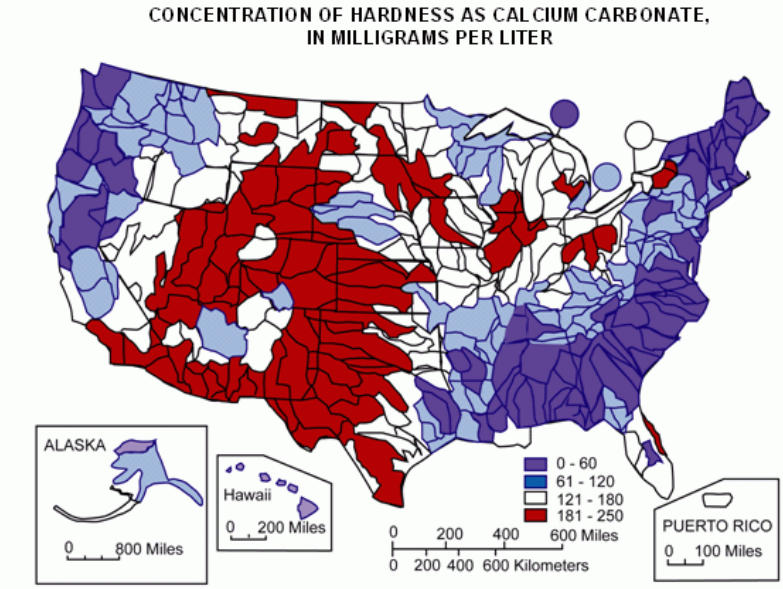
Understanding Water Quality in Your Home

Shen K. Yang

It is important to have a basic understanding of the quality of water that flows out of every faucet in our homes. The water hardness in the Las Vegas Valley is among the highest regions in the US (see map in below; copied from: http://water.usgs.gov/owq/hardness-alkalinity.html). The US Environmental Protection Agency's (EPA) standard of total dissolved solids (TDS) in water is 500 ppm. The water from the City of Henderson has a TDS value of ~400 ppm, meeting EPA standard.



Hard Water

Water hardness is caused by compounds of calcium, magnesium, and a variety of other metals. Hard water is not known to be a health risk, but a nuisance because of mineral buildup on furniture, poor soap and/or detergent performance in home laundry and washing. Use of hard water in humidifiers leaves a film of white residue on everything in the house. Calcium carbonate is the major component of the white film residue that remains on the dish surface after the dishes are dried by themselves following washing with hard water. Hard water also contributes to scaling in boilers and industrial equipment.

Water hardness is measured in units of milligram of calcium carbonate per liter of water (mg/L), or parts per million (ppm). The hardness of water is also reported in grains per gallon (gpg). One gpg is defined as 1 grain (64.8 mg) of calcium carbonate dissolved in 1 US gallon of water (3.785 liter). Thus 1 gpg translates into 17.1 ppm. Water that has a hardness less than 61 ppm (3.6 gpg) is considered soft; 61-120 ppm (3.6-7.0 gpg), moderately hard; 121-180 ppm

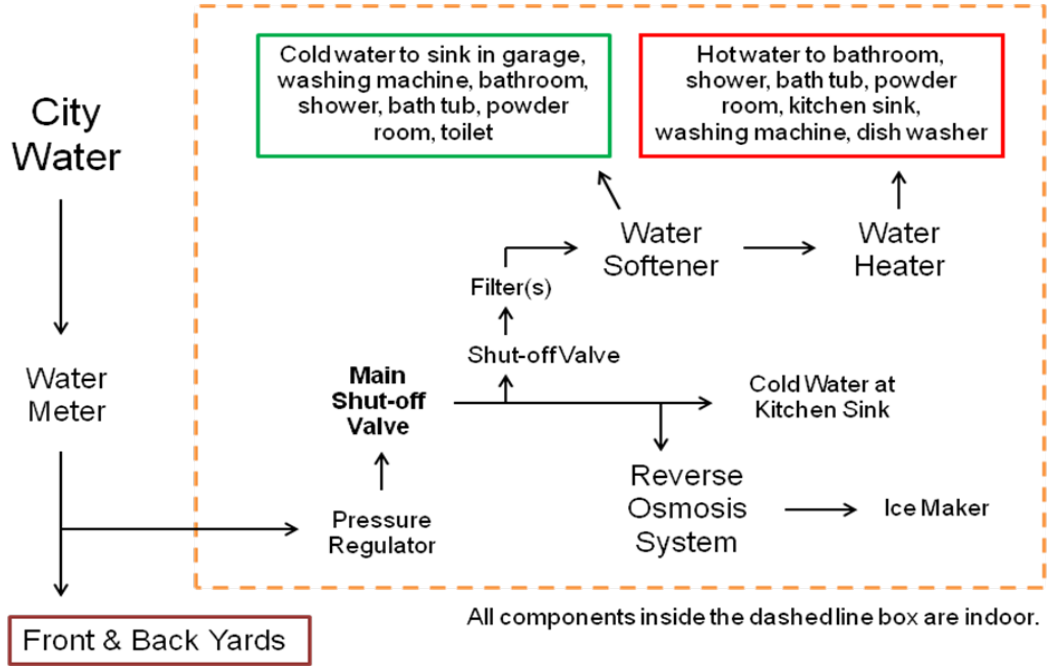
(7.1-10.5 gpg), hard; and more than 180 ppm (10.5 gpg), very hard. Water hardness can be measured either by a change in color on a paper strip coated with reagents and a color indicator or by a titration method using reagents and a color indicator. The titration method is preferred because of its relative accuracy.

There are many soluble minerals in city water. The total of all *dissolved* mineral constituents, expressed in milligrams per liter (mg/L or ppm), can be measured with a TDS meter. The EPA's TDS standard is 500 ppm (http://pubs.usgs.gov/wri/wri024094/pdf/mainbodyofreport-3.pdf). The amount of dissolved solids may affect the taste of water. Water that contains more than 1,000 ppm is unsuitable for many industrial uses. The Henderson city water coming to my house on Scotts Valley Drive had a TDS value of 405 ppm in April 2016. Using the same TDS meter in April 2016, the water of the drinking fountain and of the tap water at Anthem and Independence Centers in Sun City Anthem had TDS values of 401±2 ppm. Thus the water supply at Anthem and Independence Centers, although very hard, meets EPA standard.

It should be noted that, although both can be measured in units of ppm, water hardness measures primarily the concentration of calcium carbonate, whereas the TDS meter measures total dissolved solids which are essentially all inorganic salts including calcium carbonate.

Water Flow Diagram

The water flow paths in most homes at Sun City Anthem are illustrated in the diagram below. Filters, water softener, water heater, and reverse osmosis (RO) system are discussed in the following sections.



Major Equipment Used to Improve Water Quality

(1) Sediment and Carbon Block Filters

The sediment and carbon block filters are the first of many equipment used in the improvement of water quality. The sediment and carbon block filters are often combined in some models of water softener. Use of these filters is at the discretion of individual homeowners due to cost vs. benefit issue.

The sediment filter is used to remove rust and other water-insoluble solid matters which may be present in city water. If you have a sediment filter with a transparent housing, you may be able to observe gradual accumulation of brownish solid materials on the filter cartridge.

Carbon is the most absorbent material known. Activated carbon in carbon block filters is used to remove contaminants and impurities such as chlorine, chemicals, and volatile organic compounds.

(2) Water Softener

The water softener is used to remove primarily calcium and magnesium, which are the major cause of water hardness. Calcium and magnesium are present in water primarily as carbonate salts. Metals of calcium and magnesium are insoluble in water. Soluble calcium and magnesium are present in water as positively and doubly charged divalent ions (Ca^{++} and Mg^{++}). The calcium and magnesium ions in hard water combine with negatively charged soap molecules to form water-insoluble precipitates, commonly known as soap scum.

Water softener contains negatively charged resin (small polystyrene beads). Sodium chloride in water has positively and singly charged sodium ions (Na^{+}). The positively charged sodium ions of sodium chloride is first used to attach to the negatively charged resin in the water softener. The positively charged calcium and magnesium ions in water attach more strongly to the negatively charged resin, thereby replacing the positively charged sodium ions. This ion exchange process effectively removes a great majority of the calcium and magnesium from the water source, reducing the hardness. This "softened" water that flows out of the faucets in our homes provides increased performance of soap and detergent.

Calcium and magnesium ions attached to the resins in the water softener are subsequently replaced by sodium ions in an automatic regeneration process. This process typically takes place at around 2 AM every day, at which time the softened water is not available. The regeneration process takes 60 to 90 min to complete and makes some noise due to valve switching and fluid movement. Some models of water softener are able to monitor water usage and adjust the timing of the regeneration process.

A disadvantage in the use of sodium chloride salt in a water softener is an increase in the amount of sodium in the "softened" water. If this is a concern for some homeowners who need to maintain a low-sodium diet, potassium chloride salt may be used in place of sodium chloride

salt. However, it should be noted that potassium chloride salt is considerably more expensive than sodium chloride salt. Another disadvantage in the common use of sodium chloride salt is a very large amount of sodium salt discharged into the environment.

The anode rod in our water heater should be replaced every one to two years. By the way, the purpose of the anode rod in our water heaters is to extend the life of the water heater, rather than improving the water quality.

(3) Reverse Osmosis (RO) System

If you have a working RO system in your house, you will have a much more "softened" and better tasting water for your drinking and cooking needs. Your RO water should be as soft, if not softer, as the bottled water that you purchase on the market. The RO water is usually connected to the refrigerator-freezer for ice making and cold drinking water. The water source of the RO system is the same as that of the cold water faucet at the kitchen sink, which is the same as the city water that irrigates your trees, shrubs, and flowers in your front and back yards. The RO system removes a wide variety of contaminants including arsenic, bacteria, chlorine, lead, fluoride, chromium, radium, etc.

The basic components of an RO system are a sediment filter, one or more carbon block filters, an RO membrane cartridge, a hydraulic shut-off device, and a storage tank. The RO system is usually installed under the kitchen sink. RO systems are available with different filtration rates. A typical unit used for a family of two has a 50 gallons per day (GPD) water output.

RO works by using a pressurized water source to force water molecules across a semi-permeable membrane. Almost all (95-99%) of dissolved salts are retained on the pressurized side of the membrane and are discharged into the drain. Thus the RO system is a filtration system and the RO water is a highly filtered water. Approximately four gallons of city water are required to obtain one gallon of RO water. The water source of the under-the-kitchen-sink RO system is the same as that of the cold tap water at the kitchen sink. Due to sufficient incoming water pressure, the RO systems in the houses at Sun City Anthem do not require electricity.

As a part of the RO system, there is a stainless steel storage tank under the kitchen sink with a capacity of ~4 gallons. RO water is stored in the tank in a water bladder made of Butyl with a polypropylene lining. The water bladder has a capacity of ~2.5 gallons. There is another pressurized (7-10 psi) air bladder at the bottom part of the storage tank. The pressure of the air bladder increases when the amount of water increases in the water bladder. When the faucet of RO water is turned on, the air bladder expands and pushes out the RO water.

Residential RO systems are designed to operate at 40 to 60 psi water pressure for optimum performance. The incoming water pressure at my house is in the range of 50-60 psi. This water pressure is likely to be similar at other houses at Sun City Anthem. The maximum recommended pressure for a residence is 80 psi. The pressure of the water going into the

house can be adjusted by the pressure regulator (see water flow diagram). However, if there are no issues with the water supply in your home, there is no need to adjust the incoming water pressure.

What Kind of Water Comes Out Of My Faucets?

If you live in a house that you own, most likely you already have the water softener and the RO system installed. If you live in a rental house, you may or may not have the water softener and/or the RO system.

When the main shut-off valve in the garage is at the ON position, the city water going to the house is split into two lines (see water flow diagram). One water line provides cold water to the faucet at the kitchen sink. Another water line's outlet is in the garage, usually equipped with a shut-off valve. This outlet provides the water source to the filter(s), if present, and water softener sequentially.

The "softened" water from the water softener is split into two lines. One line supplies the "softened" cold water to the sink in the garage, washing machine, bathrooms, showers, bath tubs, powder room, and toilets. The second "softened" water line is connected to the water heater, which provides hot water supply to bathrooms, showers, bath tubs, powder room, washing machine, and dish washer. The water source of the swimming pool is city water.

The highest quality water in our homes is the RO water. Because the limited capacity of the storage tank (~2.5 gallon), the RO water should be used primarily for cooking and drinking. For an RO system with 50 GPD filtration rate, it takes ~71 min to refill the storage tank.

When you leave your home for an extended period of time, it is helpful to turn the main shut-off valve in the garage to the OFF position to stop the water going into your house. This does not turn off the water going to the front and back yards for irrigation purposes. If you have a specific need, you may stop the water going to both the front and the back yards AND the house by turning off a shut-off valve in a water meter box in your front yard near the street. The cover of the meter box is stamped with the words "City of Henderson" or "Water." It is helpful to familiarize yourself with this shut-off valve in case of emergency.

Simple Steps Homeowners Can Take

Most residents often have the following questions in their minds: Is my water softener working? Is my RO system working? For better drinking and cooking water in your home, it is advantageous to the homeowners to take action to answer these questions.

In order to enjoy the best quality of water in your house, you should ensure that the water filters, water softener, and RO system, if installed, are all in working conditions. Filters should be changed at the recommended intervals.

Water softeners are usually long-lasting and do not require frequent maintenance. You can make sure that it is working by checking the water hardness with a test strip or by a titration method. However, the required consumables for these tests may not be cost effective for homeowners who perform the test infrequently. On the other hand, the cost of a titration kit is most likely less expensive than that of a service visit by a plumber.

Quality RO water is important for drinking and cooking. A small investment that you can make is to buy yourself a TDS meter. The meter can be re-used and there are no consumables. Test your RO water with the TDS meter regularly to make sure that the RO system is working properly. It is very simple to perform the test. Compare the reading with those of a commercial bottled water and the city water. It should be noted that the TDS meter cannot be used to determine water hardness because it does not differentiate sodium ions from calcium and/or magnesium ions.

On a day in April 2016, the TDS values of the water from various faucets in my home and Costco's Kirkland purified drinking water were determined (Table 1). All faucet waters derived from the water softener had higher TDS values than that of the city water. This was likely due to an increased amount of sodium salt via the water softener. The TDS values of the RO water and a commercial bottled water were all fairly low. The results thus indicated that my RO system was performing as expected.

Table 1. TDS Value and Relative Hardness of Water in a Home at Sun City Anthem

Water	Source	TDS (ppm)	Titration Method (gpg)[1]	Titration Method (ppm)[2]
City Water	City of Henderson	405	22	376
Kitchen Tap Water (cold)	City of Henderson	403	22	376
Kitchen Tap Water (hot)	Water Softener	449	3	51
Powder Room Cold Water	Water Softener	431	2	34
Powder Room Hot Water	Water Softener	447	3	51
RO Water	RO system	17	0	0
Bottled Water[3]	Costco	19	0	0

[1]Number of drops used of the hardness 3 titrant solution contained in Hach 145300 Total Hardness Test Kit, Model 5-B, which was purchased from amazon.com. One drop is equivalent to 1 gpg calcium carbonate.

[2]One gpg of calcium carbonate is equivalent to 17.1 ppm of calcium carbonate.

[3]Kirkland signature purified drinking water purchased from Costco.

The results of the titration method (Table 1) indicated that my water softener provided us with considerably softened water and that my RO system gave us an excellent soft water. The

results were also consistent with the known fact that the water from the City of Henderson was very hard.

Summary

To ensure quality water for drinking and cooking and highly softened water for home laundry and washing, homeowners should make sure that the water filters, water softener, and RO system, if installed, are all in working conditions. Filters should be changed at the recommended intervals. Test the RO water with a TDS meter regularly to make sure that the RO system is working properly.

About the author:

Shen K. Yang （楊憲桂）
Ph.D. in Biophysical Chemistry, Yale University; Professor of Pharmacology (retired), F. Edward Hébert School of Medicine, Uniformed Services University of the Health Sciences; current resident of Sun City Anthem