Water Molecular Characteristics Contents

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pH / Acidity Description

The technical definition of pH is that it is a measure of the activity of the hydrogen ion (H+) and is reported as the reciprocal of the logarithm of the hydrogen ion activity. Therefore, a water with a pH of 7 has 10-7 moles per liter of hydrogen ions; whereas, a pH of 6 is 10-6 moles per liter. The pH scale ranges from 0 to 14.

In general, water with a pH < 7 is considered acidic and with a pH > 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5 and for groundwater systems 6 to 8.5. Alkalinity is a measure of the capacity of the water to resists a change in pH that would tend to make the water more acidic. The measurement of alkalinity and pH is needed to determine the "corrosivity" of the water.

The pH of pure water (H20) is 7 at 25oC, but when exposed to the carbon dioxide in the atmosphere this equilibrium results in a pH of approximately 5.2. Because of the association of pH with atmospheric gases and temperature, it is strongly recommended that the water be tested as soon as possible. The pH of the water is not a measure of the strength of the acidic or basic solution and alone does not provide a full picture of the characteristics or limitations with the water supply.

In general, water with a low pH (< 6.5) could be acidic, soft, and corrosive. Therefore, the water could leach metal ions such as: iron, manganese, copper, lead, and zinc from the aquifer, plumbing fixtures, and piping. Therefore, a water with a low pH could contain elevated levels of toxic metals, cause premature damage to metal piping, and have associated aesthetic problems such as a metallic or sour taste, staining of laundry, and the characteristic **"blue-green" staining of sinks and drains** . The primary way to treat the problem of low pH water is with the use of a neutralizer. The neutralizer feeds a solution into the water to prevent the water from reacting with the house plumbing or contributing to electrolytic corrosion; a typical neutralizing chemical is soda ash. Neutralizing with soda ash increases the sodium content of the water.

Water with a pH > 8.5 could indicate that the water is hard. **Hard water does not pose a health risk, but can cause aesthetic problems.** These problems include:

- Formation of a "scale" or precipitate on piping and fixtures causing water pressures and interior diameter of piping to decrease ;
- Causes an alkali taste to the water and can make coffee taste bitter;
- Formation of a scale or deposit on dishes, utensils, and laundry basins;
- Difficulty in getting soaps and detergents to foam and formation of insoluble precipitates on clothing, etc.; and
- Decreases efficiency of electric water heaters.

Iron Description

Iron and manganese are non-hazardous elements that can be a nuisance in a water supply. Iron and manganese are chemically similar and cause similar problems. Iron is the most frequent of the two contaminants in water supplies; manganese is typically found in iron-bearing water.

Sources of Iron and Manganese in Drinking Water

Iron and manganese are common metallic elements found in the earth's crust. Water percolating through soil and rock can dissolve minerals containing iron and manganese and hold them in solution. Occasionally, iron pipes also may be a source of iron in water.

Indications of Iron and Manganese

In deep wells, where oxygen content is low, the iron/manganese-bearing water is clear and colorless (the iron and manganese are dissolved). Water from the tap may be clear, but when exposed to air, iron and manganese are oxidized and change from colorless, dissolved forms to colored, solid forms.

Oxidation of dissolved iron particles in water changes the iron to white, then yellow and finally to red-brown solid particles that settle out of the water. Iron that does not form particles large enough to settle out and that remains suspended (colloidal iron) leaves the water with a red tint. Manganese usually is dissolved in water, although some shallow wells contain colloidal manganese (black tint). These sediments are responsible for the staining properties of water containing high concentrations of iron and manganese. These precipitates or sediments may be severe enough to plug water pipes.

Iron and manganese can affect the flavor and color of food and water. They may react with tannins in coffee, tea and some alcoholic beverages to produce a black sludge, which affects both taste and appearance. Manganese is objectionable in water even when present in smaller concentrations than iron.

Iron will cause reddish-brown staining of laundry, porcelain, dishes, utensils and even glassware. Manganese acts in a similar way but causes a brownish-black stain. Soaps and detergents do not remove these stains, and use of chlorine bleach and alkaline builders (such as sodium and carbonate) may intensify the stains.

Iron and manganese deposits will build up in pipelines, pressure tanks, water heaters and water softeners. This reduces the available quantity and pressure of the water supply. Iron and manganese accumulations become an economic problem when water supply or water softening equipment must be replaced. There also are associated increases in energy costs from pumping water through constricted pipes or heating water with heating rods coated with iron or manganese mineral deposits.

A problem that frequently results from iron or manganese in water is *iron or manganese bacteria*. These nonpathogenic (not health threatening) bacteria occur in soil, shallow aquifers and some surface waters. The bacteria feed on iron and manganese in water. These bacteria form red-brown (iron) or black-brown (manganese) slime in toilet tanks and can clog water systems.

Potential Health Effects

The regulations regarding iron and manganese in drinking water were established as secondary standards, which mean the limits were set because of nuisance problems and aesthetic concerns. It has come to our attention that a portion of the public may be suitable to Iron Overload or Hemochromatosis. The symptoms of hemochromatosis vary and can include: chronic fatigue, arthritis, heart disease, cirrhosis, cancer, diabetes, thyroid disease, impotence, and sterility.

Water Testing

The method used to test water for iron and manganese depends on the form of the element. If water is clear when first drawn but red or black particles appear after the water sits in a glass, dissolved (ferrous) iron/manganese is present. If the water has a red tint with particles so small they cannot be detected nor do they settle out after a time, colloidal (ferric) iron is the problem.

- **Ion exchange water softener**

  Low to moderate levels of dissolved iron, at less than 5 mg/l concentrations, usually can be removed using an ion exchange water softener. Be sure to check the manufacturer's maximum iron removal level recommendations before you purchase a unit. Capacities for treating dissolved iron typically can range from 1 to 5 mg/l. Oxidized iron or levels of dissolved iron exceeding the manufacturer's recommendations will cause a softener to become plugged.

The principle is the same as that used to remove the hardness minerals, calcium and magnesium; i.e., iron in the untreated water is exchanged with sodium on the ion exchange medium. Iron is flushed from the softener medium by backwashing (forcing sodium-rich water back through the device). This process adds sodium to the resin medium, and the iron is carried away in the waste water.

Since iron removal reduces the softening capacity of the unit, the softener will have to be recharged more often. The manufacturer of the softener medium is able to make recommendations concerning the appropriate material to use for a particular concentration of iron. Some manufacturers recommend adding a "bed cleaning" chemical with each backwashing to prevent clogging. **Not all water softeners are able to remove iron from water. The manufacturer's specifications should indicate whether or not the equipment is appropriate for iron removal.**

Oxidizing filter

An oxidizing filter treatment system is an option for *moderate levels of dissolved iron and manganese at combined concentrations up to 15 mg/l*. The filter material is usually natural manganese greensand or manufactured zeolite coated with manganese oxide, which adsorbs dissolved iron and manganese. Synthetic zeolite requires less backwash water and softens the water as it removes iron and manganese. The system must be selected and operated based on the amount of dissolved oxygen. Dissolved oxygen content can be determined by field test kits, some water treatment companies or in a laboratory.

- **Aeration followed by filtration**

High levels of dissolved iron and manganese at combined concentrations up to 25 mg/l can be oxidized to a solid form by aeration (mixing with air). For domestic water processing, the "pressure-type aerator" often is used.

In this system, air is sucked in and mixed with the passing stream of water. This air-saturated water then enters the precipitator/aerator vessel where air separates from the water. From this point, the water flows through a filter where various filter media are used to screen out oxidized particles of iron, manganese and some carbonate or sulfate.

The most important maintenance step involved in operation is periodic backwashing of the filter. Manganese oxidation is slower than for iron and requires greater quantities of oxygen. Aeration is not recommended for water containing organic complexes of iron/manganese or iron/manganese bacteria that will clog the aspirator and filter.

Hardness Description

Sources of Hardness Minerals in Drinking Water

Water is a good solvent and picks up impurities easily. Pure water -- tasteless, colorless, and odorless -- is often called the universal solvent. When water is combined with carbon dioxide to form very weak carbonic acid, an even better solvent results. As water moves through soil and rock, it dissolves very small amounts of minerals and holds them in solution. Calcium and magnesium dissolved in water are the two most common minerals that make water "hard." The degree of hardness becomes greater as the calcium and magnesium content increases and is related to the concentration of multivalent cations dissolved in the water..

Indications of Hard Water

Hard water interferes with almost every cleaning task from laundering and dishwashing to bathing and personal grooming. Clothes laundered in hard water may look dingy and feel harsh and scratchy. Dishes and glasses may be spotted when dry. Hard water may cause a film on glass shower doors, shower walls, bathtubs, sinks, faucets, etc. Hair washed in hard water may feel sticky and look dull. Water flow may be reduced by deposits in pipes.

Dealing with hard water problems in the home can be a nuisance. The amount of hardness minerals in water affects the amount of soap and detergent necessary for cleaning. Soap used in hard water combines with the minerals to form a sticky soap curd. Some synthetic detergents are less effective in hard water because the active ingredient is partially inactivated by hardness, even though it stays dissolved. Bathing with soap in hard water leaves a film of sticky soap curd on the skin. The film may prevent removal of soil and bacteria. Soap curd interferes with the return of skin to its normal, slightly acid condition, and may lead to irritation. Soap curd on hair may make it dull, lifeless and difficult to manage.

When doing laundry in hard water, soap curds lodge in fabric during washing to make fabric stiff and rough. Incomplete soil removal from laundry causes graying of white fabric and the loss of brightness in colors. A sour odor can develop in clothes. Continuous laundering in hard water can shorten the life of clothes. In addition, soap curds can deposit on dishes, bathtubs and showers, and all water fixtures.

Hard water also contributes to inefficient and costly operation of water-using appliances. Heated hard water forms a scale of calcium and magnesium minerals that can contribute to the inefficient operation or failure of water-using appliances. Pipes can become clogged with scale that reduces water flow and ultimately requires pipe replacement.

Potential Health Effects

Hard water is not a health hazard. In fact, the National Research Council (National Academy of Sciences) states that hard drinking water generally contributes a small amount toward total calcium and magnesium human dietary needs. They further state that in some instances, where dissolved calcium and magnesium are very high, water could be a major contributor of calcium and magnesium to the diet.

Researchers have studied water hardness and cardiovascular disease mortality. Such studies have been "epidemiological studies," which are statistical relationship studies.

While some studies suggest a correlation between hard water and lower cardiovascular disease mortality, other studies do not suggest a correlation. The National Research Council states that results at this time are inconclusive and recommends that further studies should be conducted.

Testing

If you are on a municipal water system, the water supplier can tell you the hardness level of the water they deliver. If you have a private water supply, you can have the water tested for hardness. Most water testing laboratories offer hardness tests for a fee, including the Environmental Quality Center. Also many companies that sell water treatment equipment offer hardness tests. When using these water tests, be certain you understand the nature of the test, the water condition being measured, and the significance of the test results. An approximate estimate of water hardness can be obtained without the aid of outside testing facilities. Water hardness testing kits are available for purchase through water testing supply companies. If more accurate measurements are needed, contact a testing laboratory.

Interpreting Test Results - Hardness

The hardness of your water will be reported in **grains per gallon**, milligrams per liter (mg/l) or parts per million (ppm). One grain of hardness equals 17.1 mg/l or ppm of hardness.

The Environmental Protection Agency (EPA) establishes standards for drinking water which fall into two categories -- Primary Standards and Secondary Standards.

Primary Standards are based on health considerations and Secondary Standards are based on taste, odor, color, "corrosivity", foaming, and staining properties of water. There is no Primary or Secondary standard for water hardness. Water hardness is classified by the U.S. Department of Interior and the Water Quality Association as follows:

Clasification	mg/l or ppm	**grains/gal**
Soft	0 - 17.1	**0 - 1**
Slightly Hard	17.1 - 60	**1 - 3.5**
Moderately Hard	60 - 120	**3.5 – 7.0**
Hard	120 – 180	**7.0 – 10.5**
Very Hard	180 & Over	**10.5 & Over**

Options

There are two ways to help control water hardness: use a packaged water softener or use a mechanical water softening unit.

Packaged water softeners are chemicals that help control water hardness. They fall into two categories: precipitating and non-precipitating.

Precipitating water softeners include washing soda and borax. These products form an insoluble precipitate with calcium and magnesium ions. The mineral ions then cannot interfere with cleaning efficiency, but the precipitate makes water cloudy and can build up on surfaces. Precipitating water softeners increase alkalinity of the cleaning solution and this may damage skin and other materials being cleaned.

Non-precipitating water softeners use complex phosphates to sequester calcium and magnesium ions. There is no precipitate to form deposits and alkalinity is not increased. If used in enough quantity, non-precipitating water softeners will help dissolve soap curd for a period of time.

Mechanical water softening units can be permanently installed into the plumbing system to continuously remove calcium and magnesium. Water softeners operate on the ion exchange process. In this process, water passes through a media bed, usually sulfonated polystyrene beads. The beads are supersaturated with sodium. The ion exchange process takes place as hard water passes through the softening material. The hardness minerals attach themselves to the resin beads while sodium on the resin beads is released simultaneously into the water. When the resin becomes saturated with calcium and magnesium, it must be recharged. The recharging is done by passing a salt (brine) solution through the resin. The sodium replaces the calcium and magnesium which are discharged in the waste water. **Hard water treated with an ion exchange water softener has sodium added. According to the Water Quality Association (WQA), the ion exchange softening process adds sodium at the rate of about 8 mg/liter for each grain of hardness removed per gallon of water.**

For example, if the water has a hardness of 10 grains per gallon, it will contain about 80 mg/liter of sodium after being softened in an ion exchange water softener if all hardness minerals are removed.

Because of the sodium content of softened water, some individuals may be advised by their physician, not to install water softeners, to soften only hot water or to bypass the water softener with a cold water line to provide unsoftened water for drinking and cooking; usually to a separate faucet at the kitchen sink.

Softened water is not recommended for watering plants, lawns, and gardens due to its sodium content.

Although not commonly used, potassium chloride can be used to create the salt brine. In that case potassium rather than sodium is exchanged with calcium and magnesium.

Before selecting a mechanical water softener, test water for hardness and iron content. When selecting a water softener, the regeneration control system, the hardness removal capacity and the iron limitations are three important elements to consider.

There are three common regeneration control systems. These include a time-clock control (you program the clock to regenerate on a fixed schedule); water meter control (regenerates after a fixed amount of water has passed through the softener); and hardness sensor control (sensor detects hardness of the water leaving the unit, and signals softener when regeneration is needed).

Hardness removal capacity, between regenerations, will vary with units. Softeners with small capacities must regenerate more often. Your daily softening need depends on the amount of water used daily in your household and the hardness of your water. To determine your daily hardness removal need, multiply daily household water use (measured in gallons) by the hardness of the water (measured in grains per gallon).

Example: 400 gallons used per day X 15 grains per gallon hardness = 6,000 grains of hardness must be removed daily.

Iron removal limitations will vary with water softener units. If the iron level in your water exceeds the maximum iron removal capacity recommended by the manufacturer of the unit you are considering, iron may foul the softener, eventually causing it to become plugged.