



Why Hard Water is a Problem

An independently verified effective solution

Introduction

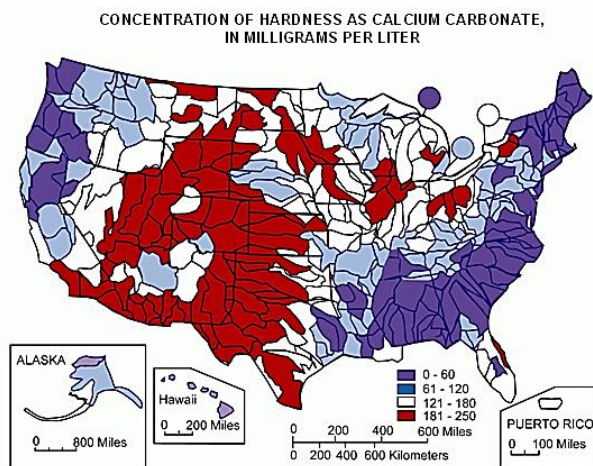
What is Hard Water?

Water is commonly called the universal solvent because it is the only liquid that has the ability to dissolve just about anything put into it (even if only a little). Unfortunately, that means that when water travels through rocks and sediment, it doesn't come out pure; it picks up some impurities like calcium or magnesium and lots of other minerals. Once the water contains enough of those minerals, it becomes "hard" water. Since the majority of our fresh water comes from underground sources, hard water is the most common water problem in the United States, affecting more than 85% of the countryⁱ.

Yet while it may not taste good, hard water is not dangerous to drink, so most people don't think too much about it (unless they hate the taste). However, hard water is not just what you drink; it's what you use to wash your dishes, take a shower, and run the plumbing. **This is where hard water causes real problems** because hard water leaves behind its impurities in the form of "scale" or "lime scale," which is most easily recognized as the white, **flaky buildup often found on faucets, showerheads, and other plumbing fixtures**. **Scale is also found inside of those plumbing fixtures, as well as inside of pipes and appliances like water heaters or dish washers.**

Why is Hard Water a Problem?

Scale-producing hard water is responsible for the loss of hundreds of thousands of gallons of water every year, wasted energy and wasted detergents. Hard water is an ineffectual cleaner, requiring more soap and longer rinse cycles to achieve the same result as softer water. Scale accumulation in a water heater acts like an insulator, meaning that a longer period of time is required to heat water wasting up to 30% more energy than a scale-free water heaterⁱⁱ. Taking longer to heat the water means people run their faucets longer, waiting for their water heater to respond, which wastes water in addition to the water heater's wasted energy.



Scale from untreated water also significantly reduces the lifespan of key household appliances such as water heaters, washing machines, and dishwashers by 25-30%, which costs consumers and businesses hundreds of millions of dollars every yearⁱⁱⁱ. Without water treatment, buying new appliances will only continue the cycle of waste and cause homeowners unimaginable amounts of stress and frustration.

Unfortunately, traditional salt-based water softeners (ion-exchange softeners) require frequent regeneration that can produce 50 gallons or more of waste water, which only exacerbates the problem. This wasted water has such a high concentration of sodium and chlorides that over time, the discharge into the environment renders it unusable by municipal systems. A single softener will waste

tens of thousands of gallons of water in its lifetime. These concerns have resulted in ion-exchange softeners being restricted or banned in thirty-four states¹.

NuvoH2O, in contrast, treats hard water without the high environmental impact of other, antiquated treatment methods or systems. That means NuvoH2O not only helps save the environment, but also saves money.

The Science behind Our Success

Understanding the Enemy

There are many factors contributing to the formation of scale. One of the most common measuring systems to track water's likelihood to create scale is the Langelier Saturation Index² (LSI).

The LSI is calculated based on the balance of calcium carbonate in water. The index number predicts whether a particular water sample will precipitate (i.e. form scale), dissolve, or be in equilibrium with carbonate. Developed in 1936 by Wilfred Langelier, the LSI index predicts the pH saturation point (pHs) for water.



The key components for carbonate equilibrium are carbon dioxide (both as a liquid and a gas), carbonic acid, carbonate, bicarbonate, and solids containing carbonate (like magnesium and calcium carbonate). The LSI is also temperature sensitive and tends to increase as the water temperature increases (meaning the likelihood of creating scale increases as water temperature increases).

By the Langelier formula, the factors that influence scale formation can be simplified to include the following:

- Alkaline pH
- Mineral (Total Dissolved Solids (TDS), Calcium and Carbonate)
- Temperature

In the same sense that building a fire requires fuel, heat and oxygen, the formation of scale requires mineral, heat and an alkaline pH.

Wilfred F. Langelier

Wilfred F. Langelier was born in 1886 in Nashua, New Hampshire. He earned a B.S. degree in chemistry in 1909 from New Hampshire College at Durham and a M.S. degree in chemical engineering in 1911 from the University of Illinois. In 1916, Langelier accepted an assistant professorship at the University of California, Riverside.

In 1936 he published a paper entitled "The Analytical Control of Anti-Corrosive Water Treatment". An index was developed in this paper which today is called the Langelier Index, or Langelier Saturation Index (LSI).

This single engineering parameter of the scaling potential of water is one of the most widely used interpretative parameters of water quality for industrial water treatment as well as domestic drinking water treatment.

Langelier remained at Berkeley until his retirement in 1955. Wilfred Langelier died September 13, 1981 at his home in Berkeley, California.



The NuvoH2O System

The NuvoH2O patented design and proprietary formulation was developed from almost thirty years of commercial experience in water treatment and purification. First designed for the food services industries to protect steam cookers, NuvoH2O's technology has helped solve complex water problems for some of the nation's largest businesses, like Walgreens, MGM Resorts, Carl's Jr., Hardee's, and many others.

NuvoH2O's residential product is a point-of-entry; cartridge-based water softening system containing CitraCharge, an FDA approved citric acid-based solution that lowers the water's alkalinity. This not only

prevents scale formation in appliances and fixtures within the home, but also removes scale that has already formed. Each NuvoH2O cartridge (shown above) typically lasts for 6 months of normal household usage.

Treating Hard Water

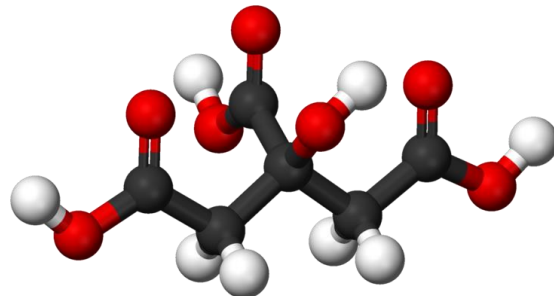
NuvoH2O treats hard water based on Langelier's formula in two ways:

First, instead of removing calcium like traditional salt softeners, the NuvoH2O system chelates (binds) and sequesters (isolates) the calcium ions, preventing it from precipitating out and forming scale. Once bound to CitraCharge, the NuvoH2O chelant, the mineral cannot form scale.

Second, NuvoH2O also lowers the measured pH of the water (lowering the LSI value) to reduce or eliminate scale formation.

Chelation

The NuvoH2O Salt-Free Water Softeners use a process called CHELATION (pronounced key-LAY-shun). Chelation involves the binding, or stabilization, of mineral ions naturally found in hard water^{iv}. The chelant in CitraCharge creates a ring structure to bind the ions to the CitraCharge instead of to other ions, which is what typically causes scale and hard-water deposits.



As a subset of chelation, sequestration is another chemical reaction of CitraCharge and the mineral ions. Like chelation, sequestration traps ions in the solution (in this case, the hard water) despite the

Threshold Effect

CitraCharge acts as a threshold scale inhibitor and can accomplish the desired effect at levels far below that which would seem to be required for a stoichiometric reaction. For example, water containing 100 parts per million (ppm) hardness could theoretically require an equal amount of CitraCharge to chelate or sequester all of the available hardness.

However, in practice, a far smaller amount of CitraCharge is required to inhibit scale formation. The formation of scale is due to the crystallization of calcium carbonates and this "threshold effect" of CitraCharge occurs by interfering with early crystal growth.

presence of precipitation agents (i.e. stuff that's trying to kick the ions out) and works as a threshold scale inhibitor^v.

Sequestration also protects your plumbing and appliances. By isolating the ions in the water, they not only can't bind to each other, but also can't attach to the ions in your pipes,

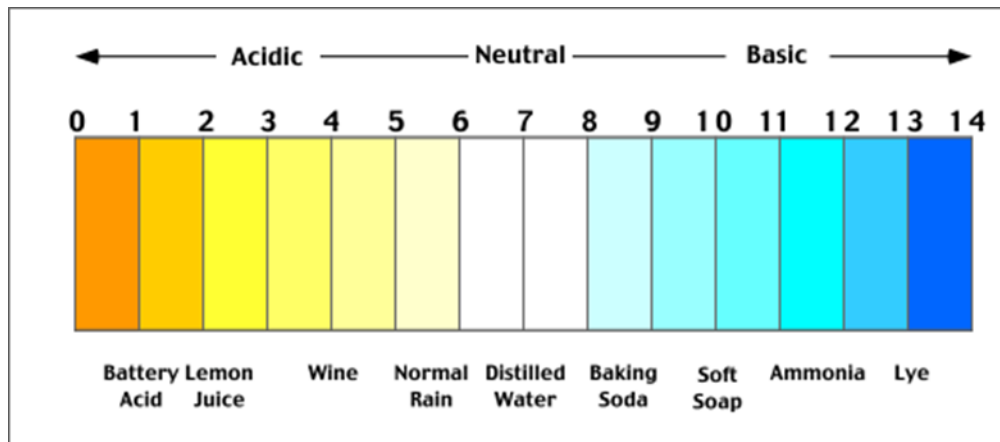
Our CitraCharge formula stops the mineral ions from causing hard water problems by making the typically troublesome minerals stay apart in the water instead of attaching to the metal in the pipes the water passes through. Since they're bound, those minerals also freely wash away from your body, hair, dishes, pipes, fixtures, and appliances.

Decades of experience and independent scientific study^{vi} has shown that CitraCharge not only inhibits scale formation, but can also help remove existing hard deposited carbonate scale. Pipes, fixtures and appliances exposed to threshold doses of CitraCharge for extended periods of time (so, for several weeks—not several minutes) first show a gradual softening of the scale followed by its slow disintegration and removal. The soft scale particles are then washed away normally, resulting in scale-free plumbing, fixtures, and appliances regardless of their initial state when the system is installed.

Acids & pH

pH is the measure of the activity or concentration of hydrogen ions in a solution. Pure water has a pH very close to 7 at room temperature. Solutions with a pH less than 7 are said to be acidic with the acidity increasing as the pH decreases. Solutions with a pH greater than 7 are basic or alkaline.

A primary ingredient in CitraCharge is an FDA approved citric acid. Citric acid is a weak organic acid that occurs in fruits and vegetables. It is a natural chelant and preservative, and is used in many foods and soft drinks. The table below has the pH measures of a number of everyday items.



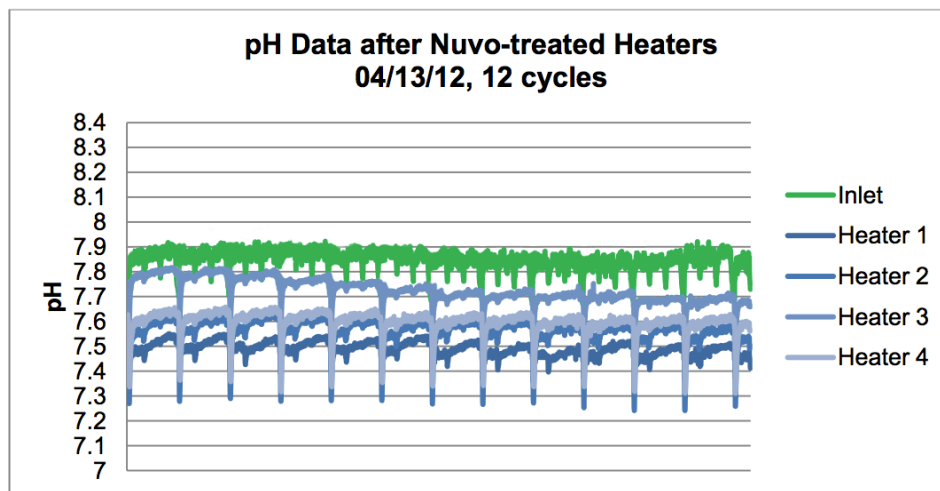
Effect of pH on Scale Formation

In addition to determining mineral hardness, pH is one of the key factors determining whether or not scale will form. The solubility of calcium carbonate is directly affected by the pH of the water. In other words, if the pH of the water is decreased, more calcium carbonate solid can be dissolved. Conversely, if the pH of the water rises, calcium carbonate particles will be forced out of solution, which then forms scale deposits.

The pH is also adversely affected by water temperature. As pH is a measure of the hydrogen ion concentration in a liquid, a change in the temperature of a solution will be reflected by a subsequent change in pH^{vii}. Gases in general, and especially carbon dioxide, are less soluble in water at high temperatures. Therefore, as the temperature rises, the dissolved carbon dioxide decreases. This increases the pH of the fluid, again reducing the solubility of the calcium carbonate and forcing the mineral to deposit.

CitraCharge naturally decreases the pH of hard water—which is nearly always alkaline—to closer to the neutral range, substantially reducing its potential for scale formation. Since the pH scale is a logarithmic scale (like the Richter scale for earthquakes), even small changes make a big difference. For example, if water measured 7.9 on the pH Scale is decreased to 7.4, it experiences a fifty-fold (50x) decrease in hydrogen ions.

The NuvoH2O System uses CitraCharge’s diluted form of citric acid to safely neutralize water’s alkalinity. Exhaustive studies have proven the efficacy of this micro-dosing, and an independent study by Battelle showed that the expected decrease in pH is .2 to .5 – or a twenty- to fifty-fold (20-50X) improvement. Furthermore, even the anticipated spiking after periods of inactivity stayed significantly below the normal range for typical hard water while still remaining above neutral^{viii}. (See figure below)



In addition, one of the primary ingredients in CitraCharge acts as a corrosion inhibitor that sticks to the metal surface of any pipe or appliance, providing a barrier to any potential corrosive elements.

Water corrosiveness can also be attributed to a number of other factors besides pH including temperature, low TDS (total dissolved solids), high flow rates, and even the presence of dissimilar metals and dissolved gases (such as oxygen and carbon dioxide). CitraCharge can help control corrosion on both ferrous and non-ferrous metals and alloys.

Measuring System Effectiveness

An ion exchange (salt) softener treats hard water by replacing the minerals in the water with sodium during the ion exchange process. The traditional measurement to determine if an ion-exchange softener is working is to test for hardness, which looks for the presence of minerals. If there are no minerals, then that system is working.

That won't work for NuvoH2O systems, however, because the NuvoH2O system chelates (binds) the calcium ion, which prevents it from precipitating out and forming scale, but it does not remove the calcium ion. NuvoH2O also lowers the measured pH of the water to reduce or eliminate scale formation. So instead of a hardness test administered for ion-exchange softeners, a pH test of treated and untreated water will indicate if the NuvoH2O system is installed correctly. If the pH is lower after water treatment, the system is functioning properly.

Leaving the Minerals in is a Good Thing

Calcium and Magnesium are essential to human health. In fact, the National Research Council (National Academy of Sciences) states that hard drinking water generally contributes toward the total calcium and magnesium needed in the human diet. Also, according to the World Health Organization, evidence of health benefits associated with the presence of calcium and magnesium in drinking water is significant^{ix}.

Softening water using ion exchange (salt) systems will reduce the natural minerals in the water by replacing them with sodium ions. Consequently, 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 8mg/liter for each grain of hardness removed per gallon of water. For example, if water has a hardness of 10 grains per gallon, it will contain about 80mg/liter of sodium after being softened with an ion exchange softener if all hardness minerals are removed.

As a result of the sodium content of softened water and potential benefits of drinking hard water, some individuals may be advised by their physician not to install ion exchange water softeners, to soften only hot water, or to bypass the water softener with cold water line (usually to a separate faucet at the kitchen sink) to provide unsoftened water for drinking and cooking. As discussed above, these issues are not a problem with NuvoH2O as our system leaves the essential minerals in the water which is a good thing for your health.

Results Independently Verified

An independent study performed by Battelle (the world's largest non-profit research and development organization in the world) studied the efficacy and benefits of the NuvoH2O System. The project was executed in two (2) phases as follows:

- 1) Phase I: Longevity of appliances (instantaneous electric water heaters were used) and fixtures (showerheads were used) and resulting energy savings for a typical household from use of the Nuvo System, and
- 2) Phase II: Removal of existing scale and prevention of future scale build-up from water heaters and resulting efficiency.

Phase 1 Results

The study discovered that, on average, untreated water heaters exhibited over 50x more scale than NuvoH2O treated water heaters. Some untreated water heaters exhibited as much as 90x to 140x more scale. That means that, on average (.87 g NuvoH2O vs. 45.6 g untreated), the NuvoH2O system effectively prevented 99% of the scale formation over the simulated 2.2 year test period^x.

The NuvoH2O-treated water heaters also took over 25% less time to achieve a steady state of operation when compared to untreated water heaters. This decrease came about because the NuvoH2O-treated elements were able to directly transfer the heat from the copper elements to the water, whereas scale on the untreated heating elements acted as a barrier to the heat transfer.



Untreated Element (Left) and Treated Elements (Right)

The study also showed that Nuvo-treated showerheads had significantly less surface scaling than the untreated showerheads. In fact, during Phase 1, numerous untreated showerheads had to be removed and cleared of scale which blocked the showerhead inlet screen. Additionally, the drain cover in which the untreated showerheads drained showed visible scale collection.

Phase 2 Results

For Phase II, untreated water heaters from Phase I were transitioned to installation with Nuvo Systems. The intention was to document the ability of the Nuvo System to remove existing scale and prevent further scaling. Over time (one (1) simulated year) the majority of heaters exhibited gains in energy efficiency and reduced time to steady state temperature. Time to steady state temperature is an important metric since the longer it takes to heat the water to the user defined setting (a common setting of 130°F was used), the more energy is required. Any reduction in the time needed to reach steady state temperature translates into direct energy savings.

Conclusion

So what can you do to prevent hard water from flushing your money down the drain? Simple: get NuvoH2O.

When installed into existing homes, not only does the NuvoH2O system prevent scale build-up, but it also removes scale that is already present resulting in improved appliance efficiency in many situations.

In summary, the use of the NuvoH2O System will (1) prevent scale to protect the appliance from the corrosive and destructive power of scale, (2) remove existing scale to produce significant energy and water savings for the consumer, and (3) will in most cases extend the lifetime of appliances due to enabling a more efficient state of operation.

ⁱ U.S. Geological Survey Open File Report

ⁱⁱ New Mexico State University, "Softened Water Energy Saving Study – Controlled Experimental Testing Program on Household Water Heaters".

ⁱⁱⁱ CSU, "Improved Estimates of Economic Damages From Mineralized Water".

^{iv} International Union of Pure and Applied Chemistry, IUPAC Defined science

^v Crabtree, "Fighting Scale – Removal and Prevention"

^{vi} Battelle Labs, Independent study "Accelerated Life Study to Evaluate Consumer Benefits of NuvoH2O Water Conditioning System".

^{vii} Zumdahl, Chemistry 3rd Edition

^{viii} Battelle Labs, Independent study "Accelerated Life Study to Evaluate Consumer Benefits of NuvoH2O Water Conditioning System".

^{ix} Cotruvo J, Bartram J, eds. Calcium and Magnesium in Drinking-water : Public health significance, Geneva, World Health Organization, 2009.

^x Battelle Labs, Independent study "Accelerated Life Study to Evaluate Consumer Benefits of NuvoH2O Water Conditioning System".