How Soft Is Soft Water?

Soft Water Is a Green Technology

By C.F. 'Chubb' Michaud, CWS-VI

Among the advantages of using soft water in the home is the ability to cut down on the amount of soaps and detergents used for clothes and dishes. *The Soap Study* conducted by the independent testing firm Scientific Services S/D, Inc. of New York in 2011—and funded by the Water Quality Research Foundation (WQRF)—showed that when you use soft water in your washing machine, you can save 50 percent on soap by cutting your detergent use in half. In addition, you can save on energy by washing in 60°F (15°C) cold water instead of the recommended 100°F (38°C) hot water and actually do a better cleaning job. Similar soap savings were shown for dishwashers as well. All of this is in addition to avoiding the extra wear and tear on appliances resulting from the use of unsoftened water in other areas of your home.[1] Longer appliance life, lower energy usage and less chemicals down the drain, on top of longer fabric life with better color retention, all bolster WQA's claim that residential soft water is a green technology. Soft water use also cuts down on the amount of work spent cleaning up after the cleaning. As much as 40 hours per year of scrubbing and wiping is eliminated through the use of soft water.

What is soft water? There is a general lack of agreement, even among professional water treatment experts as to the definition of soft water. WQA has long preached that only water of less than one grain per gallon (< 1 gpg or < 17.1 ppm as $CaCO_3$) qualifies as soft water, and *only those treatment devices that produce soft water can be called softeners*. The US Geological Survey (USGS) confuses the facts with the description of natural waters containing less than 60 ppm (as $CaCO_3$) as constituting soft water.[2] They also classify these waters as low alkalinity. The USGS definition has more to do with the inference that so-called soft water might have to be handled differently than water classified as hard. There may be restrictions of its use for irrigation and corrosivity for instance. It has nothing to do with the common use of the term *soft water* as it applies to boiler feed and residential comfort. Recently, there has even been talk that a group of professionals within the water treatment industry may like to raise the limits on so-called soft water to values along the lines of USGS. Presumably, this is to allow some of the alternative devices that do not meet the current criteria of a softening device to gain access to the term *softener* for marketing purposes (as in saltless softener). Consumers have a certain expectation for products that are advertised with respect to performance. I believe that soft water is one of those products. The purpose of this article and research is to answer the questions: "How soft is soft water? What works?"

Soap chemistry

How does soft water save on soap? Those who travel and stay in various hotels have no doubt noted that their morning showers in different cities will vary widely in the ability of soap and shampoo to produce lather. They might also note that if the hotel has an in-house laundry, the towels might feel a bit scratchy and non-absorbent. The explanation for these observations lies in the chemistry of both soap and hard water.

Water (a polar solvent), is not able to penetrate oil or grease (non-polar) by itself, not even soft water. When soap is introduced, however, it acts as a bridging or emulsifying agent for the oil/water mix, which is what cleaning is all about. Soaps are generally formulated as long-chain organic molecules (fats or oils) by reacting alkali with a fatty acid through a reaction known as saponification. The result is a new molecule with a hydrophilic end (water-loving) and a hydrophobic (or oleophilic) end (water-hating or oil-loving).[3] In the cleaning process, the oil-loving end of the molecule can interact with grease and oil (soil), which then becomes suspended in the water (stabilized by the hydrophilic end) and is washed away. Factors that increase grease solubility, such as higher pH and higher temperatures, have been the traditional wisdom used to boost the cleaning process. Soap is the sodium (or potassium) salt of a fatty acid that acts as a surfactant (surface-active agent for reducing the surface tension of water and making it wetter). Animal tallow (fat) and potash (wood ashes) were used to make some of the original soaps, a process that goes back over 2,000 years, and although modern chemistry has changed much of that, the chemical relationship of soap and how it works has not differed.

Soap acts as a water softener

While the sodium and potassium salts of these fatty acids (soaps) are water soluble, calcium and magnesium salts are not. Water hardness, the result of calcium and magnesium ions, has a stronger attraction for the soap molecule (a weak acid) than does sodium, and reacts with soap to form an insoluble soap curd (or bathtub ring). This is actually a softening process that reduces interfering hardness ions. Unfortunately, it not only removes hardness, it uses up soap in the process. Therefore, the more hardness that is present, the more soap is required to produce detergency. In very hard water, two to three times as much soap may be required.[1] Using soft water reduces the amount of soap needed. But there are additional advantages.

Washing machines are batch processes. You fill the tub with water, add soap, add dirty clothes and push the button. When the cycle goes to spin dry, the tub spins and water, soap and dirt are extracted, but not 100 percent. Even the subsequent rinse cycles leave some of the original fluids behind. The spun-dry laundry easily retains its own weight in water, along with the associated salts, soaps, soap scum, precipitated minerals, non-removed soil, etc. When those fabrics are subsequently force-dried or even air-dried on the clothesline, most of the residuals remain in the fabric. Since soft water does not precipitate with soap, it and the dirt will rinse more freely and completely, resulting in a cleaner wash. Leaving soap scum and precipitated minerals behind leads to the dulling of colors by a coating on the fibers that reduces softness and absorbency. These deposits are brittle and more rapidly hasten the abrasion of the fabric and shorten its lifespan. In addition, soap scum left behind may provide a nutritional base for bacteria and mold (often found living in a washer) and produce odor if not dried right away.

Even if one uses enough soap to overcome the initial hardness, plus enough to do the cleaning, precipitation and soap scum will still form in the rinse cycles because of the large amount of chemical (soap) left behind in the fabric and the introduction of new hardness (in the rinse water). So how soft does the water have to be to take full advantage of soft water?

Determining water hardness

One of the quick and easy demonstrations used by sales reps in presenting the benefits of softened water is the soap test, using demonstration kits from various companies. This test uses an alkaline soap and a small, capped vial. The vial is filled about half full (about 10 cc) with the test water and a single drop of soap is added from the dropper bottle. Then you shake, shake, shake and observe the foam generated. It's a qualitative test rather than a quantitative test, designed to be a black or white, hard or soft, little soap or lots of soap test. In trying several different ratios of water to soap, I found that these test kits *could* become quantitative test kits to demonstrate real soap savings between hard and soft water.

There is no question about the ability to generate a good lather using this test on really soft water. It is also very conclusive in showing the lack of suds that can be generated in very hard water. This all plays on the consumer's perception that good sudsing is a good thing. I found the amount of suds produced and how long they last is related to the amount of hardness in the water. I decided to do a little bench testing to determine just how useful this little test kit might be by trying to answer the question: "How soft is soft enough?"

I used a popular test kit to test the tap water at my lab bench and on this particular day, it came to 11+ gpg. Using a 10-inch softening cartridge with new resin, I produced a quantity of water that tested at zero hardness and blended the two waters together to exactly 10 gpg. The soap test kit instructions said to fill the test vial half full. I determined this was

Figure 1. Soap test on varying degrees of hardness

Figure 2. Double the soap

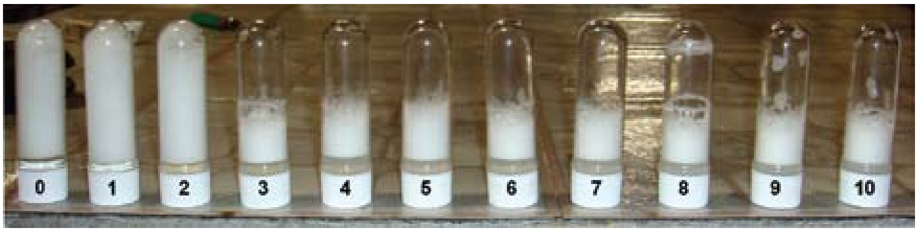


Figure 3. Half the soap

Figure 4. Half the soap after one minute

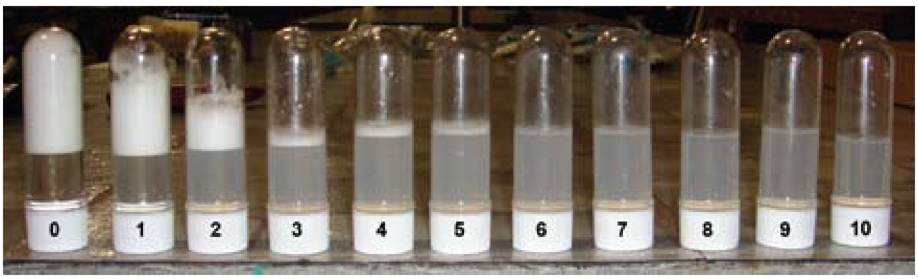


Figure 5. Half the soap after two minutes

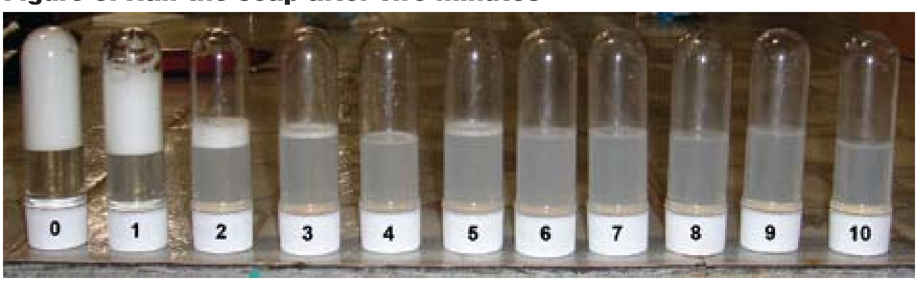
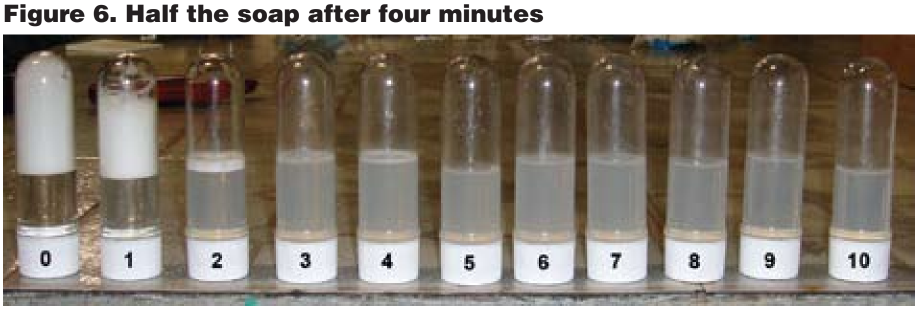


Figure 6. Half the soap after four minutes



10 cc. Using a 10-mL pipette, I made up samples in clean 35-cc, capped test tubes at zero through 10 gpg in one-gpg increments. I then added one drop of soap, capped the tubes and shook the samples. The results are shown in Figure 1.

This set certainly shows that above three gpg, on might have a tough time getting soap to do its job. I was beginning to renew my trust in the USGS. Then I added one more drop of soap to each vial and shook them again. These results are shown in Figure 2.

This set confirmed the WQRF-sponsored soap study that concluded if you use enough soap (sometimes this is more than the manufacturer recommends), you will boost detergency. There is, however, a marked departure between the two- and three-gpg samples. I decided to use a half-drop of soap (by doubling the amount of test water) and I cleaned the bottles and repeated the test. The results are shown in Figure 3.

Using the reduced amount of soap, again there was sudsing up to the three-gpg sample, but the effects of the soap having to fight the hardness was more evident. Note the haze in the samples. The high pH of the soap precipitated hardness, creating the haze; it is obvious even in the one-gpg sample. Figure 4 shows the foam height after aging for one minute beyond the initial photo.

Discussion

Although there is more to good cleaning than simply good suds, this test produces a good demonstration for soap requirements and what happens with soap and hard water. Hard water not only reduces the effectiveness of the soap, it also produces a precipitate that will dull colors, impart a rough surface to fabric and increase the wear factor of abrasion. In addition, the remnants of soap scum imbedded in the fabric increases the pick-up of new soil so clothes don't look as good as long. This is strictly a qualitative test and *cannot* be used to determine the amount of hardness present. It is a good demonstration, however, to show the effects of hard water and soap consumption.

Conclusion

The original question posed was: "How soft is soft water?" As far as consumer expectation is concerned, anything above zero is a compromise. While reasonable detergency in hard waters of two gpg or less could be anticipated, one does not realize the total savings of reduced soap usage until reaching one gpg or less. My answer to the question is predicated on the satisfaction of the customer expectation. *To realize the soap saving benefits of soft water, one has to remove hardness to < 1 gpg.*

References

1. *The Battelle Study*, Water Quality Association. 2009. www.wqa.org
2. US Geological Survey. water.usgs.gov/owq/hardness-alkalinity
3. *Virtual Chembook*, www.elmhurst.edu/~chm/vchembook/554soap

About the author

♦ C.F. 'Chubb' Michaud is the Technical Director and CEO of Systematix Company of Buena Park, CA, which he founded in 1982. He has served as chair of several sections, committees and task forces with WQA, is a Past Director and Governor of WQA and currently serves on the PWQA Board, chairing the Technical and Education Committees. Michaud is a past recipient of the WQA Award of Merit, PWQA Robert Gans Award and a member of the PWQA Hall of Fame. He can be reached at (714) 522-5453 or via email at AskChubb@aol.com

About the products

♦ The particular test kit the author used for this article was the #23052 from Pro Products, Inc (www.proproducts.com). Similar kits are also available from Hach, LaMotte, Taylor and Fuller Engineering.