Why Naturally Soft And Softened Water Are Not The Same

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1.0 Abstract

Observational studies have lead to the hypothesis of a possible inverse correlation between water hardness and cardiovascular disease mortality in the general population, that is, that there may be a link between the presence of calcium and/or magnesium in drinking water and lower rates of cardiovascular heart disease. These observations have been made of populations using naturally soft water supplies. Observational studies have an inherent limitation in that they cannot alone confirm causal inference. Yet even if the indicated association from these studies should prove true, it may not apply to water supplies that were previously hard and have been subsequently softened. This paper will discuss the significant differences between *naturally soft* and *softened* water supplies. The data to date compares only naturally soft against naturally hard water supplies. It does not relate to softened drinking water.

Public water systems such as those in Boston, Massachusetts; Portland, Oregon; Tacoma, Washington; San Francisco, California; and other places have historically come to be known as “soft water supplies.” Other characteristics of these systems, such as water corrosivity, became associated then with their labels as “soft water supplies.” While many of these waters are indeed corrosive, it is not because of “soft water.” Naturally soft water supplies have a paucity of any dissolved minerals, or an absence of total dissolved solids (TDS), an excess of carbon dioxide over alkalinity, and generally, a low pH. This is not true of softened water supplies; softened water is vastly different. It is not the absence of calcium and magnesium that causes the observed results in naturally soft water supplies, but rather the aggressive characteristics caused by the fact that naturally soft water contains less than 50 milligrams per liter of total dissolved solids, little alkalinity, and acid pH. This can lead to important differences in concentrations of distribution and plumbing system corrosion byproducts – such as lead, copper, cadmium, chromium, iron, zinc, and other heavy metals – between tap water from naturally soft water supplies and drinking water from softened water supplies.

2.0 Naturally Soft Water Supplies

Water hardness is caused by divalent and polyvalent cations dissolved in water. The most prevalent of these are the ions of calcium and magnesium. These can be present in waters at tens or even hundreds of milligrams per liter (mg/L) when the water has been exposed to sedimentary rock or sedimentary geologic formations. Water hardness is absent

however, when the water is directly from precipitation, snowmelt, or regions such as mountains where there are no sedimentary rock formations.

Waters without any appreciable calcium and magnesium exist naturally all over the world. They are commonly used for many municipal and central water systems. These naturally soft water supplies have less or comparable concentrations of calcium and/or magnesium to that of cation exchange or lime-soda softened water. In North America, naturally soft water with a paucity of water hardness along with a paucity of any dissolved minerals or total dissolved solids (TDS) content exists along both seacoasts – from the Mid-Atlantic States of Georgia and the Carolinas to Nova Scotia, Canada – and from San Francisco to Anchorage, Alaska. Table 2.1 shows typical characteristics for some of the water systems in these areas.

Table 2.1

Comparing Naturally Soft Water Supplies[2]

Supply	Calcium (mg/L)	Magnesium (mg/L)	TDS (mg/L)	Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	pH
Seattle, Washington	6. 5	1.4	41	22	7.5
Tacoma, Washington	4.5	0.9	40	15	7.0
San Francisco, California	3.2	0.6	27	9	9.1
New York City, New York	6.9	1.0	41	11	6.5
Boston, Massachusetts	4.5	0.4	31	7	6.4
Atlanta, Georgia	8.0	0.7	44	17	6.9
Savannah, Georgia	18	1.1	91	29	7.3
Portland, Oregon	1.0	0.6	22	7	6.4
Baltimore, Maryland	18	3.5	89	39	7.7
Denver, Colorado	10	2.2	39	23	7.2
Household Softened Water	1-7	0.2-2	150+	100+	7+
POU Reverse Osmosis Treated Water	1	0.1	10-50	10-50	6.5+

3.0 Consumers Would Suspect Any Waters With Lower Calcium And/Or Magnesium, Natural Or Otherwise

There cannot be any distinction or differentiation between the consequences of mineral deficiency in such consumer supplies as these with naturally soft water, and that in demineralized, softened, and bottled water. It is inherent that any effects regarding health-based calcium and magnesium compositions in treated drinking water must likewise apply uniformly across the water supply market. If users of point-of-use reverse osmosis water or desalinated water, for example, are advised that they are at risk due to calcium or magnesium deficiencies, the press and free market entrepreneurs will convince residents in naturally soft municipal water systems of the same deficiency and significant risk. Consumer perceptions in central water systems will be affected. The same advisories and policies regarding calcium and magnesium concentrations in demineralized drinking water will be applied to the major central supplies that have naturally low water hardness.

Following the advice of Dr. Frantisek Kozisek and the National Reference Center for Drinking Water[4], the Czech Republic has decreed minimum drinking water quality contents of 30 mg/L for calcium, 10 mg/L for magnesium, and 150 mg/L for total dissolved substances as well as optimum levels of 40-80 mg/L for calcium and 20-30 mg/L for magnesium. It is not unreasonable to estimate that one-quarter, one-third, or even more of U.S. and worldwide people in many regions commonly drink naturally soft municipal tap waters containing an absence of calcium, magnesium, and TDS far below these levels and at levels below or comparable to that of treated drinking water from ion exchange water softening or reverse osmosis systems. Across the Arctic and high in the mountains the world over, populations use snow melt for their sole source of drinking water. This drinking water has practically zero calcium and/or magnesium content. These people are not known to have elevated heart disease. In fact, it is quite the opposite. Greenland Eskimos, for example, are known to have a low death rate from coronary heart disease.

What perceptions should these naturally soft and low TDS water consumers have about their drinking water? It is no different in calcium and magnesium content than is ion exchange, reverse osmosis, or distillation treated water. Experts' conclusions or World Health Organization (WHO) advice about calcium and magnesium in drinking water cannot avoid affecting perceptions about naturally soft public water supplies. The overall response by the public would be to suspect any water with lower calcium and/or magnesium content, natural or otherwise.

- Should we believe municipal drinking water is related to cardiovascular disease?
- Should we believe public tap water is not as healthy as it otherwise could be?

Without testing and proving the observed association hypotheses with confirmed cause-and-effect evidence as from intervention trials, public health policy based on inconclusive or incomplete data regarding the magnitude or even the prospect of risk truly may create significant **undue alarm**. If the Safe Drinking Water Act or the public utilities refuse to

supplement calcium and magnesium into municipal waters, in light of eminent expert or WHO-related advice and findings of health significance, it will make central water system consumers of naturally soft drinking water ever more alarmed, apprehensive, unsure, and vocal. Already, since the 2003 Rome nutrition conference reports, consumers with heart disease and cardiovascular deaths in the family have begun accusations and lawsuits against soft water providers.

A counter-argument often stated is that a separate hard water supply or re-hardening filters can be provided for drinking purposes. This is not always practical. Dr. Kozisek[4], for example, says that: "Any attempts to supply the lost minerals back by means a special cartridge filled with calcium (dolomite) were proven practically ineffective with those small devices, as the "remineralizing" cartridges are not capable to enrich the normally flowing water with more than a few milligrams of calcium and magnesium." Even if it were practical, the end-user many times would be deterred from using established, safe, and reliable water treatments that would make the water undrinkable according to their newly influenced perception. The added expense of calcium and magnesium supplementation devices will likewise discourage consumers from realizing the significant beneficial enhancements of treating or purifying their household and drinking water qualities. Challenging the acceptability of water for drinking purposes – whether naturally soft, softened, demineralized, or bottled – must be balanced against the danger of driving people away from otherwise purified, protected, and safe drinking water sources.

There are numerous existing domestic and commercial installations of demineralizers, softeners, reverse osmosis, and distillation systems that would be impacted by any change in guidance or policy related to drinking water with low mineral content. Adverse publicity about treated and naturally soft water supplies will affect consumer confidence. The relevant agencies and organizations will have major difficulties as they try to accommodate the careful nutrient management required, as well as limit liability and other damages.

4.0 How Naturally Soft Water Is Different Than Softened Water

Table 4.1 depicts differences between naturally soft and softened water. In understanding the issue of soft water effects, it is important to distinguish between naturally soft and softened water. The effects of each can be drastically different. Both waters have low contents of calcium and magnesium. They are both soft waters. However, note the dramatic differences in dissolved ions or total dissolved solids content, alkalinity, and acid vs. alkaline pH characteristics. These factors govern numerous distinctions between naturally soft and softened waters much more than do the calcium and magnesium contents.

Table 4.1

Typical Naturally Soft Water	Softened Water
• Sources: rain, rivers, lakes, or snowmelt water	• Sources: Well water or spring water
• Natural absence or low amount of dissolved ions in the water	• Calcium and magnesium water hardness ions are removed and replaced, but the treated water continues to have an abundance of other dissolved cations and anions
• Low dissolved mineral total dissolved solids (TDS) levels	• Medium to high dissolved mineral total dissolved solids (TDS) levels
• Low calcium and magnesium levels	• Low calcium and magnesium levels
• Low alkalinity levels	• Medium to high alkalinity levels
• Acidic pH	• Neutral or alkaline pH
• Corrosive	• Noncorrosive

Naturally soft water, like that occurring along the coastal areas from the Appalachian and Rocky Mountain ranges in North America has low mineral content. In these areas, the underground strata are principally granite, which does not dissolve readily into the water. Thus, these naturally soft waters are typically aggressive because of the low dissolved solids content or the extreme paucity of any dissolved minerals, and are also corrosive because carbonic acidity has not been neutralized by alkalinity. However, this is not the case with water that was once hard and has been subsequently softened by ion exchange water softening.

Water treated to remove hardness is inherently and substantially different from naturally soft waters in another important way too. While water softeners take out all the hardness from the water, they also take out almost all traces of iron, manganese, lead, cadmium, barium, radium, strontium, beryllium, aluminum, and other metallic cations. Reverse osmosis systems take out these minerals even more completely. Distillers are perhaps the most efficient in this demineralization. Treatment devices may also remove such harmful compounds as nitrate, arsenic, endocrine disruptors, and many other synthetic and

volatile organic chemicals. The removal of trace metals and compounds with proven human toxicity counteracts postulated negative effects from removing the magnesium and/or calcium from drinking waters.

5.0 Corrosion and Soft vs. Softened Water

The removal of hardness with an ion exchange water softener does not affect the factors that cause or accelerate corrosion. Softening does not change the pH or carbon dioxide concentration, the dissolved oxygen concentration, or the total chemical concentration of minerals. A softener may reduce the amounts of solid and suspended particles in water, but obviously cannot change other physical factors such as temperature, flow rates through pipes, or volume of water used.

The germane question is whether sodium in water is corrosive? That is the only addition or change to ion exchange softened water. The answer, of course, is **no**. There is nothing about the chemistry of replacing calcium and magnesium ions with sodium ions that affects the corrosivity of water. Thus ion exchange softening neither causes nor controls corrosion.

Figure 5.1 depicts the chemical reactions involved in ion exchange water softening and Table 5.1 summarizes the key distinctions between softened and naturally soft waters.

Figure 5.1
Ion Exchange Water Softening Reactions

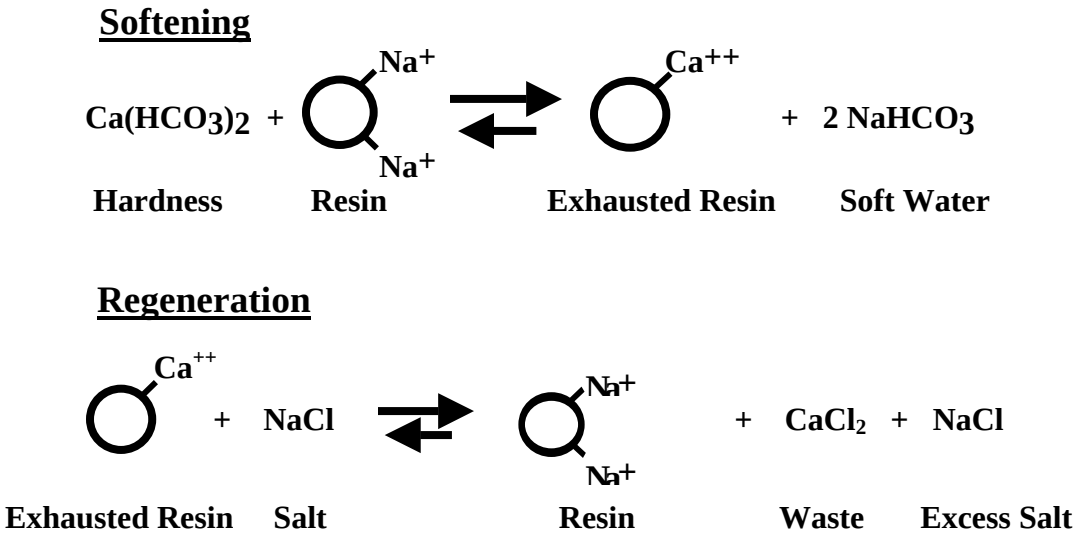

Table 5.1
Naturally Soft Water is Different Than Softened Water

Factor	Naturally Soft Water	Softened Water
pH	Usually < 7.0	Usually > 7.0
TDS	Very Low	Moderate to High
Corrosivity	Moderate to High	Same as Raw Water

A landmark study by the U.S. Environmental Protection Agency (EPA) was reported in the August 1999 *Journal AWWA* entitled "Ion Exchange Softening Effects on Metal Concentrations[7]." This article reported on research by Thomas Sorg, Michael Schock, and Darren Lytle of the Agency's drinking water research program on the question of whether ion exchange water softening has an effect on the corrosivity of water. The study was divided into phases to evaluate the effect of different water qualities. Each study phase used two identical pipe loop systems – one supplied with the hard source (control) water and the other supplied with ion exchange softened (test) water. The studies ran over three years from November 12, 1992 to November 23, 1995. In conclusion, the authors reported: "Results showed that removing hardness ions with a household water softener did not lead to a pattern of higher metal leaching from various home plumbing materials containing lead, copper, and zinc. Furthermore, the water softener did not have a detrimental effect on several significant water quality parameters that influence metallic solubility and rate of corrosion, i.e., pH, total inorganic carbon, dissolved oxygen, chlorine, temperature, and orthophosphate." This study put to rest the unproven idea that water softeners or softened water cause corrosion.

Naturally soft water, on the other hand, because of its paucity of total dissolved solids, general excess of carbon dioxide over alkalinity, and often low pH is aggressive and corrosive. Naturally soft water actually leaches more contaminants from water distribution lines and plumbing systems into the drinking water supplies. Softened water does not, rather, it removes dangerous and trace level contaminants from water supplies. This major difference between these two types of waters must be taken into account. However, the data for such differentiation in regards to calcium and magnesium health effects is grossly lacking. Comprehensive comparative studies should to be conducted to clearly determine the effect of the softening of waters and potential health outcomes.

6.0 The Data

Very few investigations have ever attempted to compare a central treatment plant using lime-soda or sodium based ion exchange softening in one community while another community nearby uses unsoftened water. Rather, all the epidemiology studies that have been considered thus far appear to have been done comparing only naturally hard and naturally soft waters. A study[1] comparing softened vs. unsoftened water, "Possible Toxic Water Factor In Coronary Heart-Disease," was published in *The Lancet*, No. 7914, Vol. I for 1975. This research found a reverse correlation between death rates for cardiovascular

heart disease and water hardness. Consumers drinking the same water that had been softened experienced a 36 percent lower cardiovascular/renal mortality rate than the consumers of this same water that was not softened, and who were located only across the river. Kansas City, Kansas has water that is more than twice as hard as the softened water of Kansas City, Missouri, from the same source. This is more evidence that the fundamental differences in the nature of softened and naturally soft waters can lead to an entirely different set of conclusions for health-related implications.

Similarly, no research has been carried out to date that compares the health of those who use home water softeners or under-the-sink reverse osmosis (RO) systems in hard water areas, to the health of those who do not use such devices. Given the positives of what these water treatment systems do accomplish, it is absolutely essential that such studies be conducted prior to reaching any conclusions that could adversely affect their use.

In the 1960s, H. A. Schroeder[5] studied mortality rates of states with average water hardness in their municipal supplies and found higher all-cause and cardiovascular mortality rates among states with softer water. However, when mortality rates in the naturally soft regions such as the Southeastern United States (Maryland to Georgia) and the rates in the naturally hard water areas such the Corn Belt and plains states (North Dakota to Kansas and Iowa) were removed, the relationship changed[6]. A National Institutes of Health review[6] of Schroeder's work found the associations between water hardness and mortality rates to be weak and inconsistent when studied in areas where extraneous variables are more uniform. Dr. A. Richey Sharrett[6] concluded the "association may be the result of regionally distributed geochemical or climatic factors related to water chemistry, or to social or other geographic factors whose association with water quality is only accidental."

7.0 Conclusion

Any recommended guidance for drinking water hardness will immediately manifest to a broad and influential public health policy. It will affect consumer attitudes toward the safety of their drinking water supplies, and it will significantly direct expenditures of resources toward public health protection. We must insist that the highest levels of evidence be used to guide and set these policies. All of the evidence so far suggest any association between drinking water calcium and/or magnesium levels and human health are observational population studies, and relate only to naturally soft and naturally hard water. They may not pertain or apply at all to the significantly different softened or otherwise treated water supplies.

No matter how competently performed, an observational or even a preponderance of many observational studies can only suggest hypotheses, which then must be tested and substantiated, as with an intervention trial. It is essential that causality be proven in public health considerations of calcium and magnesium water hardness.

8.0 References

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