

# GAC Kinetics

## Finer Mesh Carbons Often Represent the Better Option

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

### General

It is well understood that high surface area and access to that area is what separates one GAC from another. GAC does, indeed, have a very high surface area—about 1,000 m<sup>2</sup>/gm. That's over 100 football fields per pound of average GAC.

GAC functions by adsorption or adhesion. Organic molecules are drawn to the clean, non-polar surface of the GAC and are held by a molecular attraction. The forces that attract the organics and pull them out of solution must be stronger than the forces that are keeping them in solution. It is understood that organics with high water solubility (alcohols, glycols, acetone or formaldehyde) are not readily adsorbed because the forces keeping them in solution are very strong. On the other hand, those with limited solubility (gasoline, chlorinated hydrocarbons and pesticides) are more easily picked up.

### Capacity

If a typical GAC were saturated with a hydrocarbon such as benzene so that the entire surface area of the GAC was covered one molecule deep, it would contain some 2.5 cc of benzene/gm of GAC. Since one gm of GAC only has a pore volume of about 0.5 cc, it is easy to see that the entire surface area of GAC *cannot* be utilized. In reality, only about two percent of the total carbon surface is actually 'occupied' at breakthrough. Many of the pores are so small that most organics simply can not fit into them.

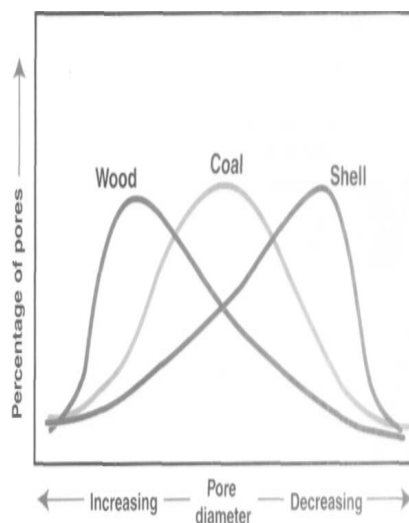
One of the keys to maximizing GAC utilization is matching the GAC to the job at hand. Different organics are of different sizes. Color bodies, dyes and natural organics are large molecules and are best treated by GAC with a higher percentage of larger pores (such as wood- or lignite-based products). Pesticides and common hydrocarbons are medium molecular weight (mol. wgt.) and respond well to coal-based GACs. The more volatile and lower mol. wgt. solvents and THMs can best be handled with shell carbons. All GACs contain large and small pores. Therefore all GACs remove most everything to some degree. The difference between them is pore size dis-

tribution (see Figure 1).

GAC granules from a single batch tend to be uniform throughout. Larger pores lead to smaller pores and provide the pathways for the adsorptive process. A poor match of the GAC and the contaminant can result in large molecules 'blocking' these pathways resulting in low capacity. Smaller molecules can get 'swept out of too-large a pore' by the fluid stream before being 'captured'. This, too, results in less than satisfactory performance.

Different sources of similar base substrates (ie the origin of the coal, wood, shell, etc.) as well as the type (i.e., bituminous, sub-bituminous, lignite, anthracite) and the manufacturing process can produce GACs of varying pore size distributions. There are, therefore, a nearly unlimited number of GAC products, some of which will work better than others despite the fact that their data sheets show similar properties. Don't be lulled into thinking you've found the best GAC for all seasons and stick with just one type or brand. The best advice is to try more than one GAC for different applications and go with the best comfort level.

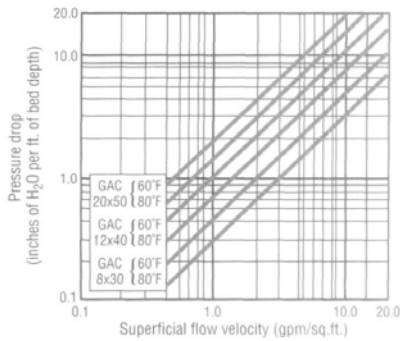
Figure 1. Typical pore size distribution for common GACs



## Match the CAC to the job

Matching the 'fit' of the GAC to the job is only one of the considerations. Another key is the particle size of the GAC. A typical 8 x 30 mesh GAC has a mean particle diameter of 2.0 mm—twice that of a 12 x 40 mesh GAC and four times that of a 20 x 50 mesh product. If we assume that GAC was a perfect cube, the 8 x 30 mesh particle would have an external surface area of 24 mm<sup>2</sup> (2x2 mm on a side times six sides). The 12 x 40 product would have an external surface of only 6 mm<sup>2</sup>. However, it would take 8

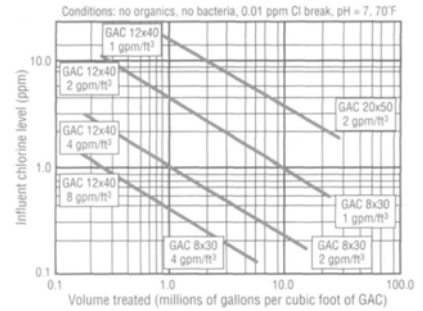
**Figure 2. Predicted throughput of influent mesh size GACs**



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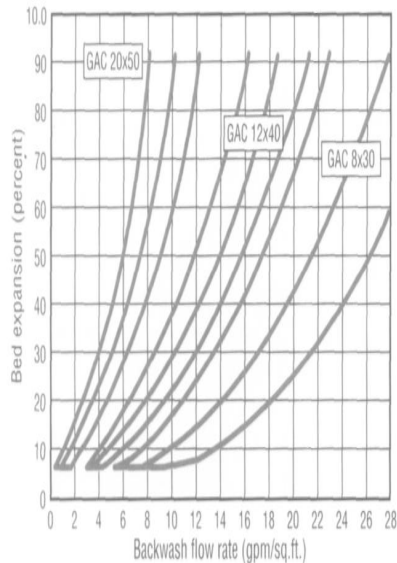
such particles to equal the weight of a single 8 x 30. Therefore, the smaller mesh would have a total surface exposed of 48 mm<sup>2</sup> for the same weight of GAC. The number of 20 x 50 particles would be twice that of the 12 x 40 and four times that of the 8 x 30. Since water can pass through all sides of the GAC surface, the finer mesh GACs will have more 'accessibility' than will the coarser mesh GACs. This means more pathways into the GAC particle which results in more rapid access to adsorption sites. We would expect the flow rates (gpm/ft<sup>3</sup>) at which we can operate the finer mesh GACs to be higher than for the coarser mesh products (with the same level of performance). Under the same conditions of operation, finer mesh GAC will have a higher capacity for the removal of a specific contaminant to a given break point. This higher reaction rate of finer mesh GAC is known as higher kinetics (see Figure 2).

**Figure 3. Relative kinetics versus mesh size**



Any GAC application will benefit from selecting the finest particle size carbon compatible with good hydraulic design. Pressure drop is the primary consideration (see Figure 3).

In addition to higher capacities and better kinetics, finer mesh GACs are easier to backwash (see Figure 4). Proper backwash is important in maintaining good distribution, removing dirt and fines and reducing bacteria growth in GAC beds. For residential and light commercial applications there are real advantages in selecting finer mesh GACs. Units can be



**Figure 4. Backwash bed expansion versus flow rate**

smaller, they will backwash more easily with limited flow rates and they will usually be less expensive to build and maintain. In addition, if you mix GAC and cation resin in a softener, the coarser sized eight and 12 mesh products require much higher backwash rates than do softeners. As a result, they drop to the bottom where they can do little to protect the resin bed. A 20-mesh GAC, however, backwashes at slightly less than that of a softener and will rise to the top, where it

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should be. Also, this gives ready access when it is time to change the carbon.

If the spent GAC you generate is to be returned to the manufacturer for reactivation, you probably won't find a taker for used 20 x 50 mesh product. Even the 12 x 40 has limitations. Reactivation reduces the size of the GAC particle. Therefore, municipalities and larger industrial users that face disposal problems with spent GAC will generally go with the coarser 8 x 30 or 12 x 30 mesh GACs because they lend themselves to multiple regenerations.

### Conclusions

Advantages for selecting finer mesh GACs:

1. higher capacities
2. smaller units
3. easier to backwash
4. less costly to build
5. less costly to maintain
6. easier to change GAC in mixed media units

To avoid high pressure drops, superficial flow velocities should not exceed 10 gpm/ft<sup>2</sup> of bed area. For typical residential needs of five gpm, a tank with a cross section of 0.5 ft<sup>2</sup> or 10-inch diameter should be used. A backwash of only three gpm would be needed for the 20 x 50 mesh and five to six gpm for the 12 x 40 (compared to eight or more for

the 8 x 30). Coconut shell GACs require higher backwash flow rates than do coal-based (because of higher density). Increase backwash flow 15 to 20 percent for shell carbons.

### About the author

• C.F. 'Chubb' Michaud, CWS-VI, is the CEO and technical director of Systematix Company, of Buena Park, Calif, which he founded in 1982. An active member of the Water Quality Association, Michaud is a member of the Board and of the Board of Governors and currently chairs the Commercial/Industrial Section (since 2001). He has served on the Board of Directors of the Pacific WQA since 2001 and chairs its technical committee. He was a founding member of (and continues to serve on) the technical review committee for WC&P and has authored or presented over 100 technical publications and papers. He can be reached at Systematic Inc., 6902 Aragon Circle, Buena Park CA 90620, telephone (714) 522-5453 or via email at [cmichaud@systematixUSA.com](mailto:cmichaud@systematixUSA.com)



# Let's Get Physical

By Charles Wysocki

" *CHEMICAL softening, ion exchange, and reverse osmosis, when used for the control of hardness, could potentially be replaced by NON-CHEMICAL WATER CONDITIONING TECHNOLOGY.* "

The above statement came from the U. S. Department of Energy in 1998—so why is there still a stigma in the United States over these type of units? There has been a lot of talk about scale inhibitors and their place in the industry for many years—maybe too much talk—but why does the U. S. not see the benefits? The following may give some explanation.

Scale inhibitors are not the be-all and end-all of protection against scale—but can anyone name a product that is? Is there one that doesn't come with its own disadvantages—whether these are cost implications, maintenance, hygiene or even environmental concerns?

As I sit on a train enduring a seven-hour journey from southern Poland to the north, I contemplate the various comments I have received in over 20 countries I visited over the past few years and always come back to the same question: why does the U. S. not see the benefits when others do?

Is it a mental block against understanding the technology? Is it something that has been thrust upon the population at an early age or is it some form of incurable disease with the words 'magnetic' and 'electrolytic' being like the

plague?

My own personal view is that in the U. S. , some of the large organizations are trying to protect their own business interests. Ignorance and lack of knowledge tend to lead to protectionism and living in the comfort zone.

Why is it that a technology that has been around for years and that was born out of research carried out by NASA, is all of a sudden classed as 'black magic' and the companies that try to promote the benefits of such units are trying to be driven out of the industry? It is as if some witch hunt is being carried out. Visiting numerous WQA exhibitions over the years I've heard some absurd comments including, 'black art' , 'black magic' and uncontrollable laughter at the first instance of these products being brought into conversation.

My own take on the issue is that these so-called engineers do not have a single clue about these products and so ridicule their existence out of ignorance. Going to a shrink, they would be diagnosed as insecure; as engineers, they believe themselves to be technically astute. I'm not sure which is correct.

## **Strong words—but true**

The biggest problem we have and have always had in this industry is the general lack of education and understanding of the products. Simply put, we are telling people to alter the

water which the municipal water companies utility authorities are supplying for washing and drinking and the consumer is asking why.

Is it any wonder that consumers are left perplexed in terms of their understanding? Is the provided water wholesome and of a high quality? And if it is in need of a second treatment, then why is it not done at source rather than at point of use? The simple answer is that it comes down to cost.

Calcium in the water is not detrimental to people's health and therefore gives an excuse of why it should be left in the supply—but calcium enriched water when heated creates a totally different and devastating result.

Figures that are bandied around in different organizations show that 4.8 mm of scale buildup on pipework can increase heating costs by 27 percent. It is therefore costing both the consumer and the environment as more fuel is needed wasted and discharged into the atmosphere. With simple technology this can be dramatically reduced.

Physical water conditioners have a part to play regardless of what some people may think or say. Why was it that not too many years ago, one of the largest water softener companies in the U. S. purchased companies in Europe whose main product line consisted of physical scale inhibitors?

The obvious answer may well be that these devices have been accepted in Europe as products that actually perform in terms of inhibiting scale formation as well as provide a good economical reason in terms of profitability. If this was not the case, would they not have sought to sell that part of the business?

I find it very strange how a number of companies seem to have double standards—physical water conditioners do not work but we sell them by the thousands in Europe! Food for thought?

The whole aspect of physical water conditioners is to offer the consumer a choice of product for an application—it should be a decision for the consumer, but how can they decide if they are not given the choice in the first instance?

We all know and agree that to get rid of scale completely, the only real solution is to install a water softener. On the other hand, maintenance costs, water usage, brine dumping and issues of drinking artificially softened water are all aspects that may call for an alternative product.

So, what are the alternatives to water softening? I pause at this moment to think of how many dealers and engineers reading this publication are flicking past this article as a bell has rung in their heads telling them not to read on—or if they do, some bad karma will happen in their lives!

So, alternatives? Not sure where to start? If we said that you could control the buildup of scale:

- without affecting the mineral content of the water?
- Without having any maintenance costs in terms of replacement product?
- With the ability to fit and forget about the product once installed?
- By using technology that is clean

and safe, which will not damage the environment?

- Without any moving parts, nothing to wear out it and can be covered by a Lifetime Guarantee?

At this stage, with any other product, people would queue up from midnight onwards outside a store, waiting for the doors to open. Where has such a revolutionary product been hiding and what has changed so it can be introduced into the market now? Nothing! The product has been around for years—a physical water conditioner which is based on either magnetic, electrolytic, electronic or electromagnetic technology.

Truth be known, these products are on sale in the U.S. even as we speak, but do not get the recognition they deserve. We sold these devices to a skeptical Canadian years ago, but seeing the results they could hardly believe their eyes. How it works, why it works, can it be true—well it was and still is.

The technology is simple—the understanding a little more confusing—and this is where the problem lies. If  $x + y$  does not equal  $z$ , it must be incorrect goes the reasoning of many. But what if  $x + y + \text{variable}$  always equals  $z$ ?

In simple terms, water contains  $+$  and  $-$  ions and as we know opposites attract, therefore, as water is heated these  $+$  and  $-$  ions come together to form limescale.

Through a physical water conditioner we induce a single polarity whereby the  $+$  and  $-$  ions all become the same (say  $-$ ) and as we know like poles repel away from each other, which prevents the formation of limescale. The calcium is held in suspension.

Recent research at Cranfield University has identified conditions under

which magnetic treatment can lead to a 70-percent reduction in calcium carbonate formation. The degree to which scale formation is inhibited has been identified as being dependent on a number of physiochemical conditions such as temperature, pH, hardness and alkalinity.

We are aware that this subject can be very contentious and controversial but the simple fact is that these products do have a place within the industry and they should be promoted by all as an economical way of reducing and controlling scale within heating systems.

Note: See scale info on our website: [www.wcponline.com](http://www.wcponline.com)

## About the company

A CALMAC LTD. specializes in the manufacture of water conditioning equipment, providing products for the domestic, commercial and industrial markets. Products include physical water conditioners, water softeners, water filters, reverse osmosis units, ultra violet disinfection units and water chillers. They may be reached at Unit 4 Crown Works, Bradford Road, Sandbeds, Keighley, West Yorkshire, BD20 5LN; Tel: 01535 210320 Fax: 01535 210321; [www.calmaqltd.com](http://www.calmaqltd.com)

## About the author

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# Presentation given at the International Symposium on Health Aspects of Calcium and Magnesium in Drinking Water (NSF/LSI/WHO) in Baltimore, Md. April 2006

## Why Naturally Soft and Softened Water Are Not the Same

By Joseph F. Harrison, RE., CWS-VI

### Abstract

Observational studies have led 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

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.

drinking water.

### 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 sea-coasts—from the Mid-Atlantic States of Georgia and the Carolinas to Nova Scotia, Canada—and from San Francisco to Anchorage, Alaska. Table 1 shows typical characteristics for some of the water systems in these areas.

### 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 wa-

**Table 1. Comparing naturally soft water supplies<sup>2</sup>**

Supply	Calcium (mg/L)	Magnesium (mg/L)	TDS (mg/L)	Bicarbonate alkalinity as CaCO <sub>3</sub> (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 softerled water	1-7	0.2-2	150+	100+	7+
POURO treated water	1	0.1	10-50	10-50	6.5+

ter, 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,<sup>4</sup> 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,<sup>4</sup> 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.

### How naturally soft water is different than softened water

Table 2 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 versus alkaline pH characteristics. These factors govern numerous distinctions between naturally soft and softened waters much more than do the calcium and magnesium contents.

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.

### Corrosion and soft versus 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 1 depicts the chemical reactions involved in ion exchange water softening and Table 3 summarizes the key distinctions between softened and naturally soft waters.

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."<sup>7</sup> 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.

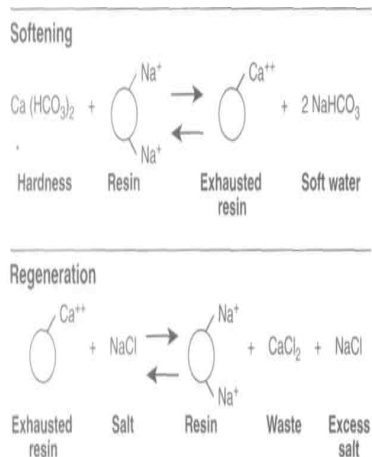
Naturally soft water, on the other hand, because of its paucity of total dis-

**Table 2. Naturally soft versus softened water**

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



**Figure 1. Ion exchange water softening reactions**



**Table 3. 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

solved solids, general excess of carbon

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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 be conducted to clearly determine the effect of the softening of waters and potential health outcomes.

**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<sup>1</sup> comparing softened versus 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<sup>3</sup> 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 mor-

tality 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.<sup>6</sup> A National Institutes of Health review<sup>6</sup> 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<sup>6</sup> 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."

## 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.

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