CENTRAL ARIZONA SALINITY STUDY – PHASE I

Technical Appendix K

HUMAN HEALTH IMPACTS FROM SALINITY IN DRINKING WATER

Introduction

Salinity is generally defined as a measure of the dissolved minerals in water and is expressed as Total Dissolved Solids (TDS) in milligrams per liter (mg/L) or parts per million (ppm). TDS is regulated in drinking water by the U.S. Environmental Protection Agency (USEPA) as a "Secondary" standard. Secondary drinking water standards are set at levels at which the water may become objectionable to consumers because of adverse taste, odor, color or appearance. Secondary standards are not directly related to adverse human health effects, but rather to consumer acceptance.

Salinity and Total Dissolved Solids

There are two general categories that are included in TDS: minerals and nutrients, and hardness. Both are summarized below:

Minerals and Nutrients: These include the regulated elements and compounds Aluminum, Chloride, Copper, Iron, Manganese, Sulfate, and Zinc. They also include the unregulated elements Phosphorus, Sodium, Potassium, Iodine, Selenium, and Silicon. Each of the constituents is discussed in the material to follow.

Hardness: Hardness may be defined as the sum of the polyvalent cations present in water. The most common such cations are calcium and magnesium. Hardness is usually expressed in terms of the equivalent quantity of calcium carbonate ($CaCO_3$). There are no distinctly defined levels for what constituents a hard or soft water supply. Generally, water with less than 75 mg/L of hardness express as calcium carbonate is considered soft, and above this value as increasingly hard.

Beginning in about the late 1950's, a series of reports, developed from statistical analyses associating cardiovascular disease and water hardness, were developed indicating an inverse relationship between cardiovascular death rates and water hardness. The tentative results seemed to indicate that the lower the hardness of the water, the higher the death rates. The questions raised by these reports remained unsolved until the National Academy of Sciences recognized that a large body of scientific information indicated a correlation between drinking water and health. This report points out that there is disagreement over the magnitude, or even the existence, of a "water factor" in the risk of cardiovascular disease. The uncertainties include the identity of the specific causal factors, the mode of action, and the specific pathological effects. The heart of the uncertainty involves the various components in hard versus soft water. There are more minerals in hard water and they may have a beneficial impact, whereas soft water is more corrosive and may tend to add potentially harmful corrosion by-products to the water. Several hypotheses have been offered on how components of drinking water may affect cardiovascular function and disease; these generally fall into one of the following classes:

1. That one or more of the principal "bulk" constituents of hardness in tap water are protective. The principle "bulk" constituents are calcium and magnesium.

2. That one or more of the trace elements that tend to be present in hard water are protective. Trace elements that have been hypothesized include lithium, vanadium and chromium.

3. That harmful metals are present in soft water, possibly having been picked up by leaching from the distribution system.

There is no clear answer at this time to define the magnitude or impact of this observation of the relationship between hard water and the apparent reduction in cardiovascular disease rates, hence the continuing uncertainty.

Historical References

Prior to the passage of the federal Safe Drinking Water Act in 1974, drinking water was regulated in some water utilities in the United States by the U. S. Public Health Service (USPHS). These utilities served water to interstate commerce, and were used to supply water to ships, airplanes, trains, and busses that carried passengers between U. S. cities; thus they were subject to the Federal Quarantine Regulations.

The USPHS established "Drinking Water Standards" in 1962, and included language relative to Chloride, Sulfate, and Dissolved Solids.

"*The importance of chloride, sulfate, and dissolved solids as they affect water quality hinges upon their taste and laxative properties. There is evidence that excessive amounts of these constituents cause consumer reactions, which may result in individual treatment or rejection of the supply. Therefore, limiting amounts for these chemical constituents have been included in the Standards."*

"It is recommended that waters containing more than 250 mg/L of chlorides or sulfates and 500 mg/L of dissolved solids not be used if other less mineralized supplies are available. This is influenced primarily by considerations of taste. Cathartic effects are commonly experienced with water having sulfate concentration of 600 to 1,000 mg/L, particularly if much magnesium or sodium is present. Although waters of such quality are not generally desirable, it is recognized that a considerable number of supplies with dissolved solids in excess of the recommended limits are used without any obvious ill effects."

These original secondary standards are now included in the USEPA National Secondary Drinking Water Regulations at the same concentration levels.

The Contribution of Drinking Water to Mineral Nutrition in Humans

The following material summarizes information on the common mineral constituents in drinking water that may be included in Total Dissolved Solids.

Aluminum: The vast majority of aluminum that occurs in treated water is as a result of the use of alum (Aluminum Sulfate) for coagulation. Aluminum occurs in approximately 30% of the untreated water supplies in the United States and varies in concentration from 1 to 2,800 parts per billion (ug/L) with a mean concentration of 74 ug/L. Aluminum occurs in approximately 50% of the treated water supplies in the range of 3 to 1,600 ug/L with a mean concentration of 180 ug/L. Aluminum is regulated as a secondary standard in the range of 50 to 200 ug/L primarily because of color and turbidity.

It has been mentioned that aluminum may play a role in the development of Alzheimer's disease; however, work done by various researchers did not find any significant differences in aluminum levels in brain tissue samples from Alzheimer's disease patients and healthy, age matched controls. There is no current direct association between aluminum in drinking water, or any other source, and Alzheimer's disease. An examination for aluminum in the diet will indicate that drinking is a minor source.

Calcium: A recommended daily intake of 800 mg has been established for adults on the basis that the daily excretion of calcium is 320 mg and that only 40% of dietary calcium is absorbed by the average American. There is no clearly defined calcium deficiency syndrome in humans, and calcium is relatively nontoxic when administered orally.

Using a national average calcium concentration of 26 mg/L and a maximum of 145 mg/L, and assuming the average adult drinks two liters of water daily, then the drinking water will contribute an average of 52 mg/day and a maximum of 290 mg/day. On an average basis this will represent 5 to 10 percent of the usual daily intake of calcium.

Calcium levels in the Colorado River average 80 mg/L. This level of calcium concentration put this source in the mid-range of the national occurrence. There is no Secondary drinking water standard for calcium, and there is no move to set an upper limit to protect public health.

Magnesium: The daily need for dietary magnesium is a function of the amounts of calcium, potassium, phosphate, lactose, and protein consumed. For the average healthy American on an average diet the daily magnesium intake requirement varies from 60 to 450 mg/day depending upon age. (The Recommended Dietary Allowance (RDA) for magnesium is thought to be 300 – 400 mg/day). Magnesium that occurs in drinking water contributes from 3 to 4% at the median range, and from 60 to 80% at the high range of concentration of the daily requirement. This is based upon the average concentration that varies from 6 mg/L median to 120 mg/L maximum in treated water supplies. Colorado River water averages 30 mg/L magnesium. Current levels of magnesium in drinking water appear to offer no threat to human health.

Phosphorus: Phosphorus, in the form of phosphate, is common to most foods and varies from a trace amount to more than 600 mg/1000 mg of foodstuff. The highest concentrations occur in nuts, beans, and grains. The average daily requirement is approximately the same as for calcium and the RDA for adults is 800 mg. Because public water supplies contain little phosphorus, and because food provides the vast amount of the RDA, it can be concluded that phosphorus levels in drinking water contribute only a negligible amount to the daily intake.

Sodium: Sodium is an essential element, and is required for nutrient transport. The total intake of sodium is influenced mainly by the use of salts as an additive to food. An examination of the average market basket indicates that from 6,700 to 6,900 mg/day of sodium is consumed in an average diet. Grain and cereal products contain the highest amount of sodium and beverages, including drinking water, only contribute an average of 20 to 30 mg/day. The sodium content of drinking water is extremely variable and one national survey found that drinking water varied from 4 to 80 mg/L with a mean concentration of 28 mg/L. The estimated adequate and safe intake for adults for sodium from 1,100 to 3,300 mg/day; infant requirements vary from 115 to 750 mg/day. Sodium research needs, especially for infants, include the relationship between sodium and potassium ratios, and the determination of total sodium intake via the diet.

Data suggests that health benefits could accrue to certain segments of the population from a reduction in sodium intake. This applies to individuals on sodium-restricted diets that are limited to less than 2,000 mg/day. With this exception the amount of sodium contributed by drinking water is generally negligible. Sodium is not regulated in drinking water, however the USEPA has included sodium on their Drinking Water Contaminant list (CCL). Specifically, the USEPA has decided to include sodium on the CCL as a research priority to evaluate and revise the current outdated guidance document for sodium. Although the American Heart Association has suggested that sodium in drinking water be limited to 20 mg/L, the USEPA notes that this level is probably low and in need of revision.

Sodium in drinking water is generally naturally occurring; however, excess sodium can be added by the use of home water softeners. Sodium concentrations in the Colorado River average 100 mg/L.

Potassium: According to one national survey potassium in drinking water varies from a trace amount to 8 mg/L with a mean concentration of 2 mg/L. Potassium is present in many foods and is useful as a food additive, often to replace sodium. The RDA for potassium for adults varies from 1,900 to 5,600 mg/day; the requirements for infants vary from 600 to 4,600 depending upon age. Potassium is not regulated in drinking water, and because levels in drinking water are low in relation to food, the contribution of potassium to the daily diet is negligible.

Chloride: Chloride is the most important anion in the maintenance of fluid and electrolyte balance and is necessary to the formation of hydrochloric acid in gastric juices. Chloride is found in practically all-natural waters, and is regulated as a secondary standard by the USEPA at 250 mg/L.

The presence of chloride in drinking water can produce a taste impact that is sometimes objectionable to consumers. Various studies indicate that adverse taste impacts may occur with chloride concentrations from 210 to 310 mg/L.

Current dietary intake of chloride varies largely with the use of salt, and estimates vary from 2,400 to 14,400 mg/day. No RDA for chloride has been established.

Chloride in the Colorado River averages 90 mg/L. The chloride is from naturally occurring sources, although some input from agricultural and other sources is possible. At these levels, drinking water contributes from 7 to 8 percent of the lower estimate of total daily chloride intake. Consumption of chloride in reasonable concentrations is not harmful, but elevated amounts may contribute to adverse taste impacts, and if the chloride is present due to the use of salt, the elevated sodium that results may be harmful to individuals on sodium restricted diets.

Iodine: Sources of iodine include foods, water and medication. In the United State the major contribution of iodine comes from salt, bread, milk, and seafood. Drinking water contains a small and variable amount of iodine. The RDA for iodine for adults varies from 80 to 140 micrograms per day, and assuming water consumption of two liters per day, drinking water provides an average of 0.3 percent of the total intake.

Iron: The amount of iron consumed per day varies widely, and occurs in many foods. The most amount of iron is contained in meats, poultry, fish, cereals, vegetables and bread. Concentrations vary in drinking water, and average 0.240 mg/L with some supplies reported as high as 1.5 to 2 mg/L. The RDA for iron varies from 10 to 18 mg/day depending on age and sex.

Assuming two liters of water consumed per day containing the national mean concentration of iron, this source will supply from 3 to 5 percent of the RDA in adults. Iron is regulated as a secondary standard in drinking water at 0.300 mg/L because of adverse color impacts. Iron, when oxidized, will produce a red or brown staining color that is objectionable to consumers.

Copper: Copper is an essential element and is contained in many foods. A RDA for copper has been established at from 2 to 3 mg/day. Typical copper concentrations in drinking water will provide from 6 to 10 percent of the estimated daily safe intake. Copper is regulated as a secondary standard at 1 mg/L primarily based on adverse color and staining considerations. A Maximum Contaminant Level Goal (MCLG) for copper has been established at 1.3 mg/L based upon health effects, and this amount has been exceeded in some supplies due to corrosion of plumbing materials.

Zinc: The importance of zinc to the human diet has been recognized for many years. An adult requirement for zinc has been set at 15 mg/day, and normal zinc concentrations in drinking water will supply 3 percent of the daily requirement. The highest observed concentration of zinc in drinking water may contribute up to 20 percent of the daily requirement.

Zinc occurs in many foods, and may occur in drinking water from natural sources of from zinc compounds added to water treatment plants for corrosion control purposes. Zinc is regulated as a secondary standard in drinking water at 5 mg/L. Because zinc is an essential element and nutrient for humans, and because there are some indications of zinc deficiency in children, any possibility of detrimental health impacts from zinc in drinking water is considered to be extremely remote.

Selenium: Selenium is an essential element and nutrient for humans. Intake from food sources varies widely due to concentrations from soil, and worldwide total daily intake varies from less than 60 to more than 300 micrograms per day (µg). An estimated adequate and safe intake for adults varies from 50 to 200 (µg). Selenium is regulated as a primary health based standard both as an MCLG and as a Maximum Contaminant Level (MCL) at 0.050 mg/L. Selenium is considered to be a problem for aquatic habitat and in some areas drinking water that meets the human health based standards may present a problem for aquatic habitat or other environmental indicator species.

Most diets in the United States provide approximately 150 micrograms of selenium per day, and the average selenium concentration from drinking water will provide from 1 to 2 percent of this requirement.

Manganese: Manganese naturally occurs in food and water. The average daily intake of manganese ranges from 2 to 9 mg/day, and the average "market basket" survey intake is 4 mg/day. The mean manganese concentration in drinking water is 22 ug/L. There has not been a RDA established for manganese, and the usual intake appears to be adequate for adults. Assuming a daily water intake of 2 liters, manganese in water will contribute an average of 3 percent of the daily intake. Manganese is regulated as secondary standard by the EPA at 0.05 mg/l or 50 ug/l.

Silicon: Silicon has not been established as an essential element and nutrient in humans. Concentrations of silicon, as silica, in drinking water vary from a trace to 72 mg/L in the100 largest cities in the United States.

No information is available on essential dietary levels, but drinking water has not been shown to be an important source or potential public health problem. Silicon is not regulated in drinking water.

Sulfate: Sulfate is found almost universally in natural waters in concentrations ranging from a trace to several thousand milligrams per liter. A survey conducted in 1970 found a range of 1 to 770 mg/L in supplies in the United States with a median concentration of 46 mg/L. The major adverse impact of elevated sulfate levels (around 1000 mg/L) is the laxative effect. Sulfate levels at 500 mg/L will taste bitter but there is a taste threshold for sulfate between 300 and 400 mg/L with some individuals able to detect levels as low as 200 mg/L. A RDA has not been established for sulfate.

Sulfate is regulated as a secondary standard by the USEPA at 250 mg/L based upon both taste and laxative effects.

The Colorado River contains approximately 250 to 260 mg/L sulfate. The USEPA is considering establishing an MCL for sulfate as a primary health based standard, and concentration from 300 to 500 mg/l have been considered.

Summary

The total dissolved solids in the Colorado River is higher than the Secondary standard promulgated by the USEPA. The sodium concentration in the Colorado River is above the 20 mg/L value suggested by the American Heart Association, but within the national normal values observed the national normal values observed in other utilities.

The sulfate concentrations in the Colorado River are near or above the USEPA recommended secondary standards. No other individual constituents of TDS are outside of the reported or regulated national normal values.

Concentrations of TDS in the Colorado River water and concentrations of some of the individual constituents undoubtedly contribute to adverse taste in the drinking water in some locations. While adverse health impacts cannot be demonstrated from consumption of Colorado River water, the high TDS undoubtedly causes some consumers to reject the supply and turn to other sources. This may be viewed as an “adverse impact” to those consumers. This impact must be considered in decision making for blending and selection of sources.

TABLE 1
CONTRIBUTION OF U.S. DRINKING WATER
TO MINERAL NUTRITION OF HUMANS

NUTRIENT AND IN WATER, (mg/L)	TYPICAL LEVEL, (mg/day)
Calcium	26
Magnesium	6
Phosphorus	ND
Sodium	28
Potassium	2
Chloride	21
Copper	0.1
Zinc	<0.2
Selenium	0.001
Manganese	0.025
Silicon	7.1

A question associated with Public Health to research and resolve:

RO home units – Is Bacterial Re-growth a Serious Health Issue for In-home RO units? Is product water disinfection required for In-home RO units?

Low pressure RO systems generally refer to those systems with water feed pressure of less 100 psig. These are the typical countertop or under sink residential systems that rely primarily on the natural water pressure to make the reverse osmosis process; a typical system includes the following Pre-filter, Reverse Osmosis Module, Post Filter, and Diaphragm Pressure Tank. Other RO systems may include GAC filters and sometime a disinfection unit, e.g., ultraviolet light.

Low pressure units typically provide between 2 and 15 gallons per day of water, with an efficiency of 2 to 4 gallons of reject water per gallon of treated water. Water purity can be as high as 95 percent. These systems can be highly affordable, with countertops units starting at about $150, and under sink units starting at about $500. These units produce water for a cost as low as ten cents per gallon once maintenance and water costs are factored in. Maintenance usually requires replacing any pre- or post-filters (typically one to four times per year); and the reverse osmosis cartridge once every two to three years, depending on usage. (1)

Quality of RO Product Water

It has been reported that bacteria can "grow" through membranes. The mechanism by which bacteria pass through a RO membrane is not known and no correlation exists between a dye leak test of the membrane and its bacterial retention efficiency. Researchers at the Center for Disease Control (CDC) conducted extensive investigations on the bacterial contamination of RO systems used in producing purified water dialysis. They reported: 1. certain naturally occurring Gram-negative bacteria can multiply in relatively pure RO water; 2. thorough periodic disinfection of the entire RO system is essential in producing water with acceptable bacterial counts; 3. stagnant water in pipes down stream of the membrane is the major source of bacteria and endotoxin in the product water; and 4. the efficiency of a membrane in rejecting is better in continuous than in intermittent use. The U.S.E.P.A. has listed RO technology as suitable for all small public water systems. It is assumed that the technology is also acceptable for in-home use as well. The U.S.E.P.A. has noted that due to the typical membrane pore sizes and size exclusion capability (in the metallic ion and aqueous salt range); RO filtration is effective for removal of cysts, bacteria and viruses. (2)

Health Significance of Bacterial Re-growth

Bacterial re-growth is common in water and has been observed even in distilled water. In water distribution systems, the Heterotrophic Plate Count (HPC) can occasionally be elevated and there have been concerns that this flora could contain opportunistic pathogens. (3)

It is well established that reports of the incidence of waterborne illness among users of household water treatment products are essentially nil. The Water Quality Association (WQA) white paper cites over a dozen objective studies on this topic. The data all document the absence of any correlation between use of Point-of-Use (POU) and Point-of-Entry (POE) products and increased rates of illness or the presence of coliform or any disease-causing organisms.

The University of Quebec studies in 1991 and 1997 documented substantial protection from gastrointestinal illness in person with POU water treatment equipment. The first study found there was 34% less illness among those using reverse osmosis. The second Payment study was less dramatic, finding 14 – 40% of gastrointestinal illness to be avoidable by using RO, depending on the age of the people (the 40% higher illness incidence is for the children 2 – 5 years old who used flowing or flushed tap water.) These POU health benefits occurred in spite of "very high levels of heterotrophic bacteria." U.S. Environmental Protection Agency studies have concluded that, "although the heterotrophic plate count (HPC) of the filter units often reached high levels, the bacteria that were found in the product water do not appear to be of health concern. They may however, be a significant factor in preventing pathogenic strains of bacteria from colonizing and persisting in GAC filter cartridges." (4)

Disinfection and Biological Re-growth

Chemical Disinfection

There are several possible ways to disinfect water within a home RO treatment system: Iodine, silver, copper, quaternary, ammonium compounds, and some other chemical agents have been proposed and are sometime used to inactivate waterborne pathogens. However, none of them are considered suitable for long-term use to disinfect drinking water for various important and valid reasons. Iodine is difficult to deliver to water and can adverse health effects, silver and copper are to difficult to deliver to water and primarily only bacteriostatic, and quaternary ammonium compounds are limited in availability, costly and not effective viruses and parasites. However, iodine, either dissolved in water or in the form of an iodinated exchange resin, has been used for short-term water treatment by outdoor recreationists, field military personnel, and persons displaced b natural disasters and human conflicts. Silver is used as a bacteriostatic agent for POU or household water treatment by storing water in vessels composed of silver or passing water through porous or granular filter media impregnated with silver. However, the extent to which silver alone inactivates microbes in water is limited, bacteria may develop silver resistance and many microbes, such as viruses, protozoan cysts and oocysts and bacterial spores, are not inactivated at silver concentrations employed for POU drinking water treatment. These agents are not recommended for routine disinfection of household water. (5)

Disinfection by UV Radiation

The UV radiation technology is simple to use and highly effective for inactivating microbes in drinking water, and it does not introduce chemicals or cause the production of harmful disinfection by-products in the water. While UV lamp disinfection systems have been widely used to disinfect drinking water at the community and household levels, no epidemiological studies of intervention type that document health impacts at the household level have been reported for this technology. There are no reasons to doubt the efficacy of sound UV lamp disinfection technology to adequately disinfect either household or community drinking water when properly applied.

There are a few concerns that do arise from using UV radiation as a drinking water disinfectant at the household level. It does not provide a chemical disinfectant residual to protect the water from recontamination or microbial regrowth after treatment. A reliable and affordable source of electricity is required to power the UV lamps. The UV lamps require periodic cleaning, especially for systems using submerged lamps, and the have a finite lifespan and must be periodically replaced. The technology is of moderate to high cost when used at the household level. Despite these drawback and limitations, UV irradiation with lamps is a recommended technology for disinfection of house water. (5)

Continuous or Periodic Sanitization

There are two basic approaches for controlling bacterial growth in a water system. One is to maintain a residual level of biocidal agent within the system (continuous dosing). This is similar to the common technique where municipal water treatment facilities inject enough chlorine, or chloramines, into their treated water to provide a residual throughout the United States, and typical minimal target residual is 0.2 mg/L. In the U.S., the most commonly used chemical in point-of-use water treatment systems is chlorine.

The second approach is to periodically sanitize the system. Whether a periodic or continuous approach is used will depend on the quality of the product water required. For instance, those systems producing "ultapure water" where no chemical residual can be tolerated in their product water must employ periodic cleaning and sanitizing instead of continuous dosing of a biostatic chemical. Most systems using continuous dosing will also need a regular, although less frequent cleaning and sanitizing regimen. Even when ultraviolet lights post-treatment with heat or biocide addition in the storage and distribution system is done, the whole system will require periodic sanitization. (6)

Finished Water Storage

The one remaining portion of the RO system where bacterial re-growth may occur is in the finished water storage tank. Re-growth may occur in the finished water storage tank when the water stored is not systematically changed to keep a fresh supply in storage.

One manufacturer, Watt Premier, recommends an annual sanitization of the entire RO unit (including the storage tank) when changing filters. Otherwise, there is no sanitation/disinfection of the water either in or for the finished water storage unit. If additional disinfection is required, the finish water will have to be either boiled or be given the addition of a disinfection product, e.g., household bleach. (7)

Question: Hard water and Water Softening – What is the impact of excess Na+ in the drinking water supply caused by the water softening process?

Hardness in Drinking Water

Hardness is defined as those minerals that dissolve in water which have a divalent (i.e., "positive two") electrical charge. Minerals are composed of either atoms or molecules. An atom or molecule that has dissolved in water is called an "ion". An ion exchange water softener can reduce or eliminate hardness problems.

The primary components of dissolved hardness are calcium (Ca^{++}) and magnesium (Mg^{++}) ions; dissolved iron (Fe^{++}) and manganese (Mn^{++}) ions may also be considered in contributing to the hardness of water. (**Note**: one grain per gallon is equal to 17.1 mg/L.)

Health Effects

The presence or absence of hardness in drinking water is not known to pose a health risk. Hardness is normally considered as an aesthetic water quality factor. The presence of some dissolved mineral material in drinking water is typically what gives water its characteristic and pleasant "taste". (1)

Normal Sodium Consumption

It is estimated that the average person consumes the equivalent of 2 to 3 teaspoons of salt per day from all sources. This is about 8 to 15 grams. Some of this salt is in the food naturally, but most of it is added in processing, preservation, cooking, and at the table. A salt (sodium chloride) intake of 8 to 15 grams is equal to about 3 to 6 grams (3,000 to 6,000 milligrams) of sodium.

Sodium in Softened Water

Since sodium is added to water softened by the cation exchange process (mechanical water softening), the level of sodium in softened water may be of interest to persons on sodium restricted diets.

The table below shows the amount of sodium added to softened water of varying original hardness. The harder the water originally, the more sodium that is added.

Sodium Added to Water from Cation Exchange Softening	
Initial Water Hardness	**Sodium Added By Cation Exchange Softening Of Water**
Grains Per Gallon	Milligrams Na+ / gallon
1	**30**

5	**149**
6	**179**
7	**209**
8	**239**
9	**269**
10	**298**
15	**447**
20	**596**
30	**894**
40	**1,191**

Contribution of Sodium from Water Softening To Total Sodium Intake

Assuming a daily intake of 5 grams (5,000 milligrams) of sodium in food and the consumption of 3 quarts of water (used for coffee, tea, food preparation and drinking) the contribution of the sodium (Na+) in the water from the home water softening process compared to the total daily intake can be seen in the following table.

Sodium Intake from Softened Water Compared to Total Sodium Intake				
Initial Water Hardness	**Salt in Softened Water**	**Salt From Food**	**Total Salt Consumed**	**% Of Total Salt From Softened Water**
Grains Per Gallon	Milligrams Na+ / 3 quarts	Milligrams Na+	Milligrams Na+	%
1	**23**	**5,000**	**5,023**	**0.4%**

5	112	5,000	5,112	2.2%
10	223	5,000	5,223	4.3%
15	335	5,000	5,335	6.5%
20	447	5,000	5,447	8.2%
30	670	5,000	5,670	12.5%
40	893	5,000	5,893	15.2%

Sodium Restricted Diets

Persons who must restrict their sodium intake to 500 milligrams per day should consume water that contains no more than 20 milligrams of sodium per quart. This is assuming that most people consume about three quarts of water per day from all sources (beverages, food preparation, and drinking). 20 milligrams per quart X 3 quarts = 60 milligrams total daily from water.

The 60 milligram level has been suggested since the basic 500 milligram therapeutic diet actually contains about 440 milligrams of sodium from food. This allows 60 milligrams of sodium from water.

If sodium (Na+) is restricted to 1000 milligrams per day, the upper limit for total sodium content of water is about 200 milligrams or about 66 milligrams per quart if three quarts are consumed.

See the following table for original hardness limits of softened water for different levels of water consumption.

Original Hardness Limits of Softened Water Allowable for Sodium Restricted Therapy				
Total Sodium Level Permitted	Total Sodium Allowed From Water	Original Hardness Limits	Original Hardness Limits	Original Hardness Limits
Milligrams Na+	Milligrams Na+	Grains Per Gallon If Consumption of Softened Water Is **3 Quarts**	Grains Per Gallon If Consumption of Softened Water Is **2 Quarts**	Grains Per Gallon If Consumption of Softened Water Is **1 Quart**
500 mg.	**60 mg.**	**2.6 gpg**	**4 gpg**	**8 gpg**

1,000 mg.	**200 mg.**	**8.8 gpg**	**13 gpg**	**26 gpg**

If an ion exchange water softener is to be used in a home where a person is on sodium-restricted therapy and water hardness is great enough that excess sodium may be consumed by using softened water, a by-pass can be installed to provide unsoftened water for drinking and cooking.

In some localities the sodium content of the municipal water supply and water from wells may also be higher in sodium than can be allowed.

Persons on sodium-restricted therapy can obtain advice from a physician or dietician. The municipal water department will provide a detailed analysis of the water supply. Detailed analysis of well-water can also be obtained. Contact the municipal water department, the Public Health Service, local water softening dealer, or the Cooperative Extension Service for the name and address of a laboratory which makes this analysis. (2)

The above information has focused upon the impacts of water soften by ion exchange processes upon human health. There is another form of impact caused by using water softening technologies to improve household water quality, i.e., ion exchange resin regeneration and the associated impact upon the community's wastewater treatment system. That issue is the subject to the following discussion.

Water Softening and Regeneration

Water softeners are one of the most effective means of treating hard water, caused by an excess of minerals -- primarily calcium and magnesium -- in the water. There are two basic types of water softeners: self-regenerating water softeners and exchange tank systems.

Residential self-regenerating water softeners are plumbed into the home's water supply and work by eliminating dissolved minerals through a process called ion exchange. Inside each water softener is a mineral tank that is filled with small plastic beads (also known as resin) that are negatively charged. To balance the charge, positively charged sodium ions are present on the beads. A separate brine tank holds a sodium chloride (salt) solution, which is used to regenerate the softener. Under normal usage, hard water is passed through the mineral tank. The calcium and magnesium ions in the hard water have a stronger positive charge than the sodium ions on the resin. Therefore, the calcium and magnesium ions replace the sodium ions on the resin. The water flowing through the softener is now considered "soft" because the majority of the calcium and magnesium in the water has been replaced with sodium.

Eventually there will not be enough sodium left on the resin to effectively soften the water. Then the softener has to be regenerated. This process is usually done during the middle of the night because soft water is not available during the regeneration. To start the regeneration, salt water from the brine tank is sent to the mineral tank. The high levels of sodium in the brine force the calcium and magnesium off the resin, replacing it with sodium. The chloride present in the brine water simply stays in solution. After regenerating the mineral tank, the brine solution is flushed to the sewer. New salt must be added to the brine tank on a regular basis to replace the salt that is used to regenerate the mineral tank. *Because chloride is not used up during the exchange* *process, eventually all of the chloride added to the mineral tank in salt will end up being disposed of to the wastewater collection system as spent brine.* (Italics are added for emphasis.) In a recent Chloride Source Study (Study) (3), performed by the County Sanitation Districts of Los Angeles County (District), data was collected to illustrate the distribution of the inputs of chloride from the overall community as wells as from residential water softening systems. In general, Chloride in the studies sewerage system comes from the following sources: Industrial (3%), Commercial (4%), Water Supply (42%), Residential (47%), and Disinfection (4%). The source breakdown of residential chloride includes the following: Human waste (16%), Laundry (12%), Pool backwash (1%), and Self-regenerating water softeners (69%). Based upon the results of this study District established two ordinances to prohibit the installation or assisting in the installation of residential self-regenerating water softeners in the Santa Clarita.

The aim of the ordinances is to reduce the amount of chloride entering the Santa Clara River (River). The River is the last natural river in Southern California. Wastewater generated in the Santa Clarita Valley, from actions such flushing toilets and washing laundry, is sent to the District's water reclamation treatment plants for treatment. The treated water leaving the plants that is not directly reused for landscape irrigation and other applications is sent to the Santa Clara River. If present at high levels in the river, chloride can harm wildlife and have a negative impact on farms that rely on river water for irrigation. Currently, the concentration of chloride in the river is twice the acceptable level established by the state Regional Board.

According to the Study, the largest source of chloride in the Santa Clarita area is residences, particularly residences using self-regenerating water softeners. Residential self-regenerating water softeners account for over half of the chloride coming into the treatment plants. If the discharge of the brine from the self-regenerating water softeners is not controlled, the Districts will have to install very expensive new treatment units at its treatment plants in the Santa Clara valley to remove the chloride.

Another finding from the Study included operational data collected for a typical home self-regenerating water softener is as follows: the concentration of chloride in the brine waste from the softener ranged from 7,000 to 13,000 mg/L, with an average of 10,300 mg/L chloride. The average volume of brine waste discharged was 47 gallons. These results indicate that for each regeneration of the self-generating softener approximately 4 pounds of chloride are used. Although homes with water softeners may be able to use less detergent and thus decrease chloride loadings from cleaning operations, this decreases is not enough to offset the increased chloride loading from regeneration of a self-regenerating water softener.

Exchange tank softeners work in a manner similar to self-regenerating water softeners, but feature a removable mineral tank that is replaced with a fresh mineral tank when the sodium on the resin is depleted. The depleted tanks are regenerated by water conditioning services at off-site facilities.

While the hardness ion, Calcium and Magnesium, are temporarily captured on ion exchange sites, the ions are eventually release back into the wastewater collection system during the water softeners regeneration cycle. Not only are the hardness ions being returned to the collection system, but an additional amount of chloride is being added to the system. The Sodium ion is either going into solution as part of the soften water or remaining on exchange sites as the replacement ion for the hardness ions. As noted above, the average brine waste concentration from a water softener is 10,300 mg/L. The residual impact of the Chloride in the system may be somewhat diluted with the flow volume in the collection system during the early morning hours. It has been estimated that an ion exchange water softener may add about 500 mg/L TDS to the portion of the community's wastewater that has been softened.

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