

**“Bucking the Industry Trend...**

**Simple Change to Water System Saves  
New Jersey Manufacturer \$23,000 Annually”**

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**Summary:**

Over the past two decades, the trend in the water treatment industry has been towards more and more complex water treatment technologies and discounting past knowledge as old-fashioned. Often lost is a true understanding of water chemistry by some current “industry experts” and the simple, economic solutions to water treatment problems. Simple water treatment solutions, properly applied, can save a considerable amount of money on operating expenses. One of these simple, economic, and proven technologies is water neutralization.

This paper shows a high acidic water, 5.5-6.0, treated using a water neutralizer, prior to a Reverse Osmosis system, saved over \$23,000/year in downstream operation expenses at a New Jersey manufacturing plant. With an investment of less than \$7,000 and operational and labor costs of only \$700/year, the Return on Investment was less than three months. While not a solution for all systems with reverse osmosis and high acidity, discussing neutralization with a qualified vendor can save Electrodeionization and/or Service DI operational expenses.

**What is Alkalinity?:**

The technical definition of alkalinity “is a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate.”<sup>1</sup> More simply stated, the definition goes on to say “In the natural environment carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere.”<sup>2</sup>

In this paper, we will be showing how this presence of carbon dioxide in water will impact the economics of your water treatment system.

**Osmosis versus Reverse Osmosis:**

The term osmosis is defined as, “the diffusion of fluid through a semi-permeable membrane from a solution with a low solute concentration to a solution with a higher solute concentration until there is an equal concentration of fluid on both sides of the membrane”<sup>3</sup>. As the name implies, a Reverse Osmosis, RO, system does the exact opposite. Reverse osmosis is achieved by forcing a high concentrate solution through a semi-permeable membrane at a pressure higher

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than osmotic pressure. This high pressure is provided by a booster pump, which reverses the normal flow of the solution. The semi-permeable membrane holds back a majority of the dissolved substances yielding a low dissolved solids level in the product water.

RO is a well-established water treatment process used in the production of high purity water. As a stand-alone process it will remove over ninety five percent of the total dissolved solids from the water it treats. For more critical applications, requiring what is commonly known as ultra high purity water, further treatment called polishing of the RO product water is required. For these applications the additional treatment usually takes the form of either mixed bed ion exchange polishing or Electrodeionization, EDI.

Regardless of the polishing technology employed, a thorough understanding of water chemistry and RO pretreatment options will reduce the overall cost of producing ultra high purity water. This is achieved by enhancing the performance of the RO system, which in turn drives down the cost of the required downstream treatment. In some cases, such as where the RO influent pH is adjusted to optimize the rejection of feedwater alkalinity, the savings can be quite dramatic.

### **Limitations of Reverse Osmosis:**

One limitation of an RO system is the membranes are semi-permeable and some dissolved substances and/or gases, specifically alkalinity, will pass through the membrane should the alkalinity exist as carbon dioxide. This is universally true in the case of older RO systems using cellulose acetate membranes and often true with even the latest form of high rejection thin film composite membranes. In view of this membrane characteristic, it is important to properly adjust the feedwater chemistry so that all the dissolved solids, including alkalinity, are impermeable to the membrane. Doing so will enhance the system rejection rate and improve the quality of the RO product water.

To explore this phenomena let's take a look at the different states carbon dioxide will exist in water and how pH adjustment can affect the permeability of the substance.

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**Different Forms of Carbon Dioxide in Water:**

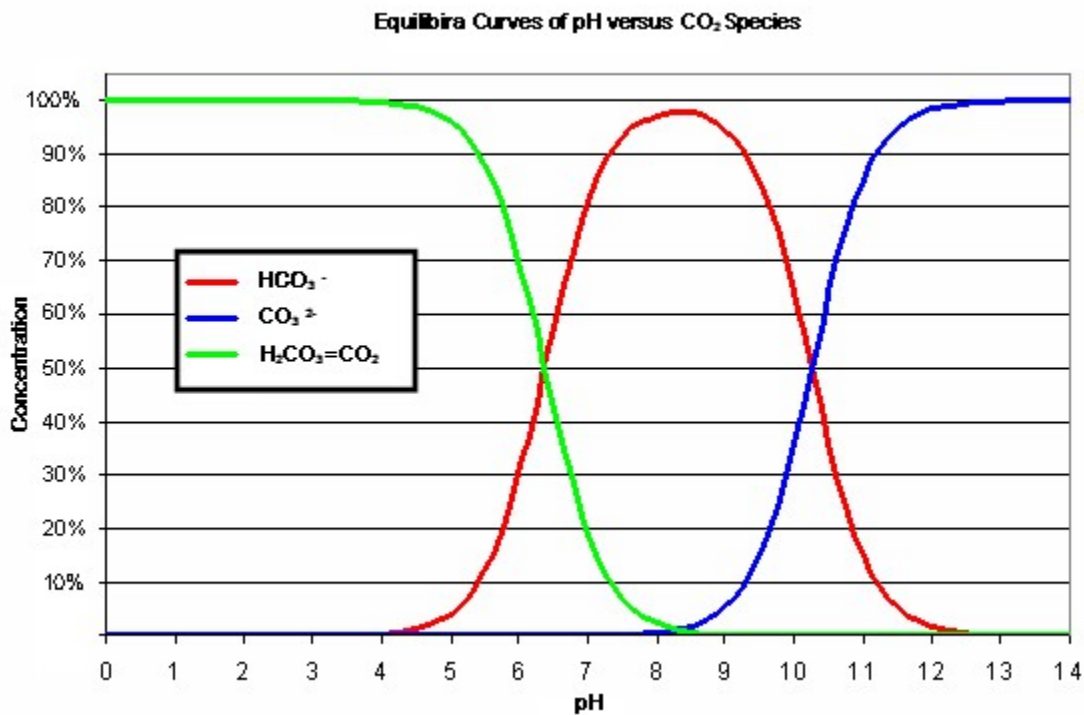
Carbon dioxide, CO<sub>2</sub>, is a gas that dissolves in water. The form or "species" in which the dissolved carbon dioxide exists is a function of the hydrogen ion concentration or pH of the water. The forms of dissolved carbon dioxide present in water are as follows and all forms exist in equilibrium:

Bicarbonate - HCO<sub>3</sub><sup>-</sup>

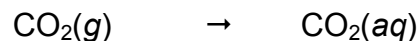
Carbonate - CO<sub>3</sub><sup>2-</sup>

Carbonic acid - H<sub>2</sub>CO<sub>3</sub>

The concentration of each form is a function of pH. The following graph shows the relationship of pH versus bicarbonate, carbonate, and carbonic acid.

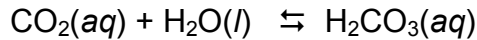


Carbon dioxide is a linear double bond between two oxygen atoms and a carbon atom. When it first dissolves in water the following reaction occurs:



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When carbon dioxide dissolves in water, the other reactants present, mainly the hydrogen ions, determine the ultimate state for the substance. This reaction will reach an equilibrium state throughout the body of the solution. The carbon dioxide will react with the hydrogen ions present in the water and an equilibrium state is established between the dissolved CO<sub>2</sub> and H<sub>2</sub>CO<sub>3</sub>, carbonic acid.



Typically only about 1% of the dissolved CO<sub>2</sub> exists as the anion, H<sub>2</sub>CO<sub>3</sub>, however, if there is an overabundance of hydrogen ions, acid water, aqueous CO<sub>2</sub> will be reduced to H<sub>2</sub>CO<sub>3</sub>, carbonic acid. Water containing dissolved carbon dioxide in this form will typically have a pH of 6 or lower. The problem presented by dissolved carbon dioxide forming carbonic acid, is that carbonic acid cannot be isolated in water<sup>4</sup>, and, therefore, cannot be filtered out by mechanical means, such as RO.

Dissolved carbon dioxide in the form of carbonic acid will pass through an RO system and subsequently load up the anion portion of either the mixed bed polishers or the EDI system. This additional load on the mixed bed greatly reduces run time. Consequently, the operating costs for effective ion exchange treatment will be increased dramatically due to the need for more anion capacity or increased frequency of regeneration. Conditioning of the dissolved carbon dioxide to a solute the RO will reject precludes the need for additional anion capacity and maintains regenerant costs at acceptable levels.

Carbonic acid cannot be isolated in water, however, other forms of dissolved carbon dioxide can. Carbonic acid is a weak acid, which dissociates in two steps. The first dissociation of carbonic acid will form a bicarbonate ion. Bicarbonate will typically exist in water with a pH of 7. The second dissociation forms carbonate, which typically exists at a pH above 8. Below are the equations for the dissociation of dissolved carbon dioxide.



The dissociation step pertaining to this treatment issue is carbonic acid's release of a single hydrogen ion to form bicarbonate.

At a neutral pH the bicarbonate species will bind with salts present in the water<sup>5</sup>. A simple acid neutralizer will do just that by dissolving calcium carbonate into the water so the carbonic acid will dissociate into carbonate salts. These carbonate

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salts will be isolated from the water and rejected by the RO system. As such, the treatment load is diverted from traveling downstream to the anion resin, thus reducing polishing system operating costs. The same effect could be achieved by injecting an alkali, like sodium hydroxide, into the RO feed water with a small chemical feed system. This approach is inherently risky. In the presence of any feed water hardness, calcium sulfate and/or magnesium sulfate can precipitate within the RO membrane modules with the possibility of permanently fouling them.



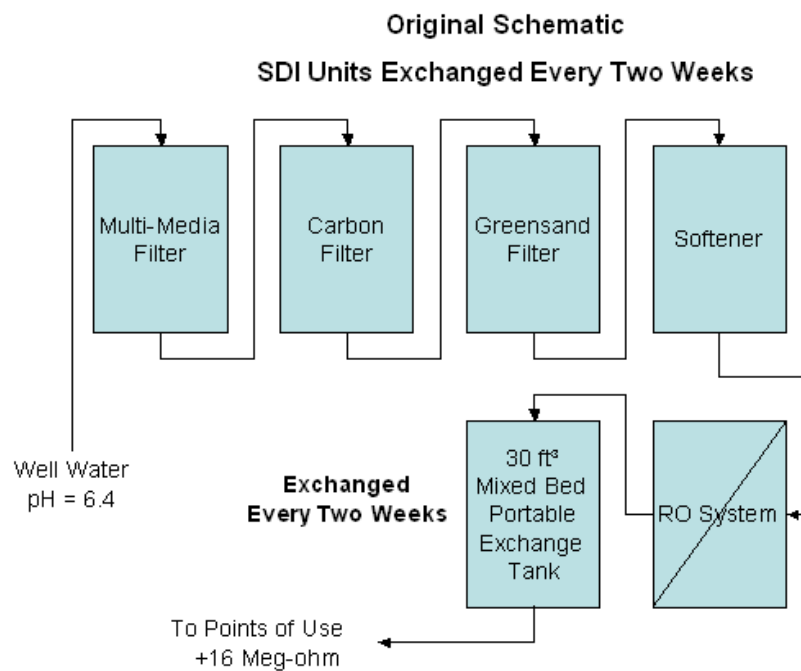
**DO NOT EVEN CONSIDER A CAUSTIC FEED SYSTEM UNLESS THE FEEDWATER HAS BEEN PRE-SOFTENED AND THE OPERATION OF THE WATER SOFTENER IS IMPECCABLE.**

A decidedly safer and simpler approach is to simply add a properly sized acid neutralizer. Acid neutralizers have no moving parts and unlike chemical feed systems do not require pH sensors, metering pumps, or any ongoing calibration services. Properly sized, an acid neutralizer only requires a periodic addition of the neutralizing media to produce a consistent and reliable pH adjusted water supply to any given RO system.

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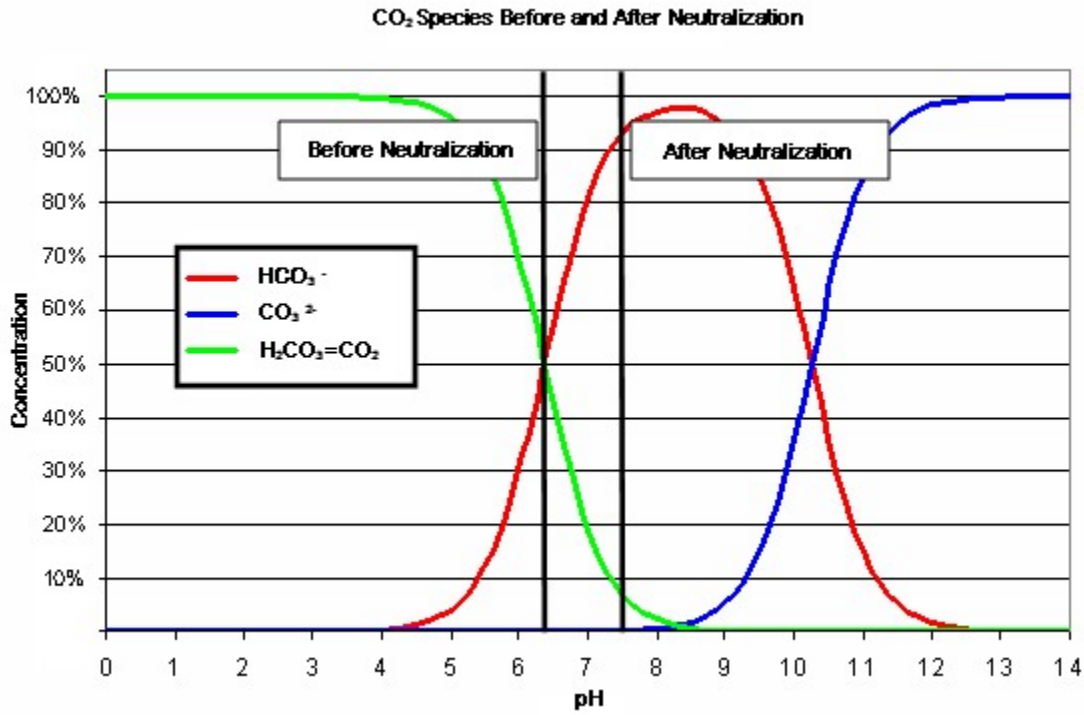
**Operating Experience:**

A New Jersey based chemical company required 20 gpm of ultra high purity water with a minimum resistivity of 16 Meg-ohms to support their manufacturing operation. Their water treatment system was comprised of a multi-media filter (anthracite, garnet, sand and gravel), carbon filtration, a greensand filter, a water softener, and a RO system. The raw water was from a well with a pH of 6.4. The post RO final polishing was done with 30 ft<sup>3</sup> mixed bed portable exchange tanks provided by a local DI service company.



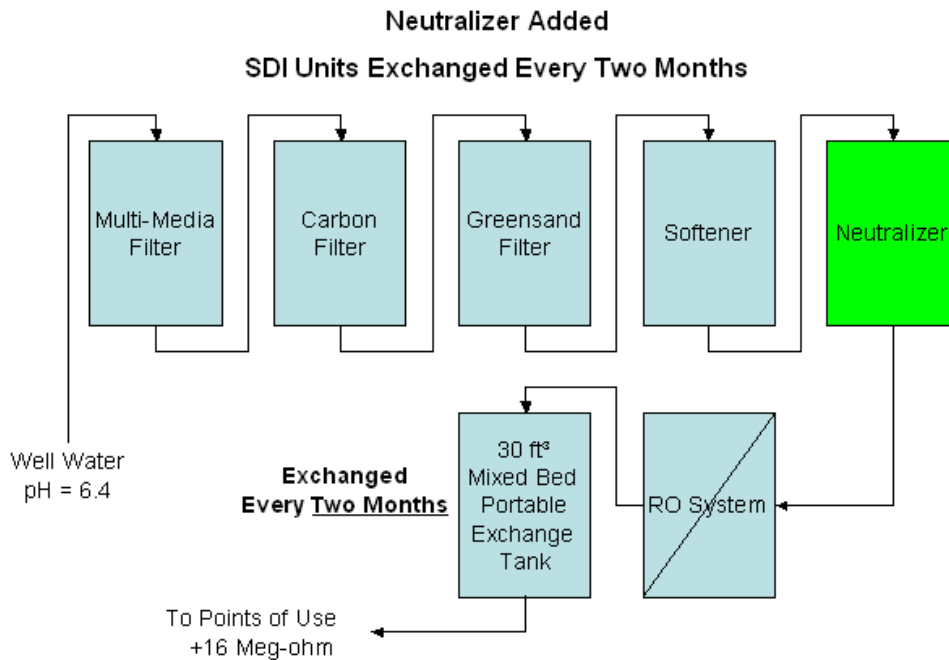
After a water audit of the entire system by Res-Kem engineers, it was decided to install a neutralizer after the multi-media filter to both maximize the performance of the RO system and to extend the life of the polishing mixed beds.

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Prior to the installation of a neutralizer, the customer exhausted and exchanged a single 30 ft<sup>3</sup> mixed bed vessel once every two weeks on average. After the installation of a neutralizer, which allowed the RO to reject the incoming alkalinity, the exchange rate of the mixed bed vessel was reduced to a minimum of once every 2 months.

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The capacity of each 30 ft<sup>3</sup> mixed bed exchange vessel was rated at 240,000 grains for which the New Jersey chemical company was paying approximately \$1,200 per exchange. The addition of the neutralizer and the resulting reduction of dissolved carbon dioxide dramatically increased the efficiency of the RO and decreased the load on the mixed bed by approximately 75%. As a result the company realized a savings of \$1,980 per month in polishing DI costs starting day one.

The improvement in mixed bed performance reduced annual operating costs by 75% allowing the capital expenditure required for the neutralizer to be recaptured within three months. Going forward the only expenditure associated with the neutralizer will be a periodic replenishment of the inexpensive neutralizing media. The actual frequency of replenishing the neutralizing media is a function of the pH of the incoming water. In the case of this New Jersey chemical company, they add neutralizer media twice a year at an estimated cost including labor of less than 30% of the price to exchange a single mixed bed polishing tank.

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**Conclusion:**

Buck the trend in the water treatment industry towards more complex water treatment technologies. Use the simple, economic solutions to water treatment problems used for many decades. Simple water treatment solutions, properly applied, can save a considerable amount of money on operating expenses. Neutralization as a pretreatment strategy is an example of one of many simple ways to optimize your water purification system, but it's not a “one size fits all” solution for every application.

Whether your facility is using an on site regenerable polisher, an EDI polisher, or a service DI company, it's imperative to get a complete water analysis prior to determining the best course of treatment. As conditions may vary depending on the season, it is also prudent to be aware of seasonal influent water quality changes to allow for adjustments in regenerations or vessel exchange rate. Discussing your water treatment requirements with a qualified, experienced water treatment systems and service vendor is strongly encouraged.

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<sup>1</sup> <http://en.wikipedia.org/wiki/Alkalinity>

<sup>2</sup> <http://en.wikipedia.org/wiki/Alkalinity>

<sup>3</sup> <http://www.yourdictionary.com>

<sup>4</sup> Chemistry, Academic Press, 1984, page 891

<sup>5</sup> Chemistry, Academic Press, 1984, page 892