# Review of Packed Bed Ion Exchange for Total Activated Carbon and Color Removal in Florida Groundwater Over the Last 15 Years

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Packed, or fixed bed ion exchange has been used extensively for the removal of total organic carbon (TOC) and color from Florida groundwater for more than 15 years. Through the application of an organic selective anion exchange process, many communities around the state have greatly enhanced and brought into compliance their finished water quality. Because it also handles a wide range of organic compounds, this technology can simultaneously eliminate the formation potential of trihalomethanes (THMs) and haloacetic acids ($HAA_5$), commonly referred to as disinfection byproducts (DBPs), as well as the pervasive issue of color removal. With a compact footprint, minimal waste stream, and no moving parts or complicated hydraulic balancing, packed bed ion exchange has been demonstrated to be the lowest-cost and most successful solution for Florida groundwater treatment.

Tonka Water is involved with the application of fixed bed ion exchange for water treatment in Florida, with over 10 facilities in operation or under construction (Figure 1), ranging from 175 gal per minute (gpm) to 30 mil gal per day (mgd).

## Technology Background

A broad term used to describe organic molecules of varying sizes, weights, and polarity in a water supply, TOC in water sources is the result of decaying vegetation, animal, and human waste. It is often responsible for color, taste, and odor, and when chlorinated, certain TOC molecules react to form THMs and $HAA_5$. Through research, these classes of disinfection byproducts have been linked to cancer, and maximum contaminant levels (MCLs) are now being enforced by the U.S Environmental Protection Agency.

Ion exchange is a recommended technology to remove TOC from a water source prior to chlorination, thereby reducing the disinfection byproduct formation potential of the water. This is especially applicable in Florida, where chloramination is extensively used. Removing organics prior to chloramination can avoid THM excursions in distribution, as biological growth occurs in older waters. Ion exchange can eliminate potential food sources for organic-producing nonpathogenic biological activity in distribution systems.

By definition, ion exchange is a process in which ions are exchanged between a solution and an insoluble (usually resinous) solid. A negative charge on the organic molecules allows the TOC to exchange on a properly conditioned anion resin with another anion of less selectivity or charge. In the case of TOC removal, the TOC molecule is exchanged on the resin surface for a chloride ion. In addition to the exchange removal mechanism, selecting the right macroporous resin allows for surface adsorption to take place concomitant with ion exchange. The abundant surface area and makeup of the correct macroporous resin allows for maximum exchange sites and locations, where surface adsorption can occur.

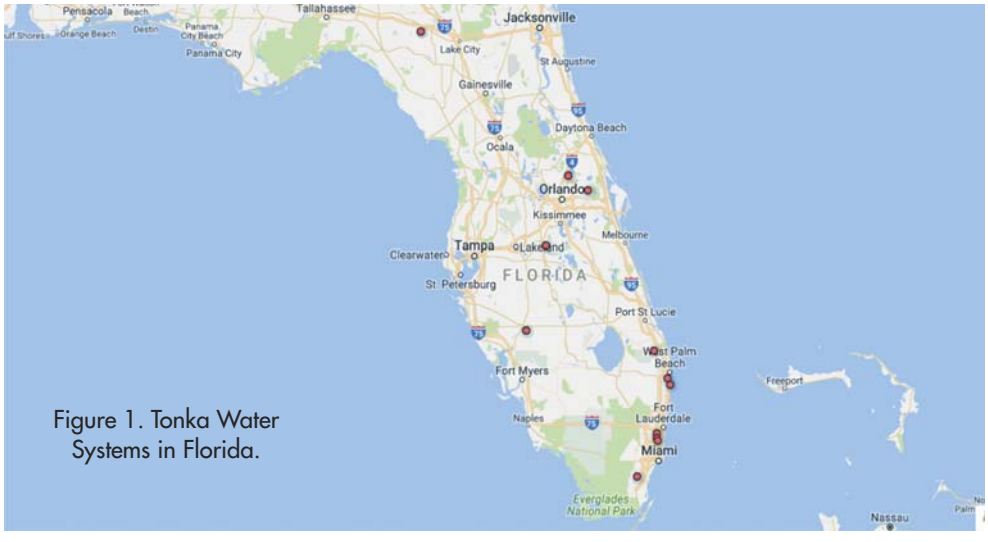


Figure 1. Tonka Water Systems in Florida.

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As treatment progresses and additional raw water-containing TOC is treated by the resin, more of the exchange sites are occupied with TOC, ultimately reaching a point of resin saturation. Prior to the breakthrough point, which is based on raw water quality, type of organics, gallons treated, and ultimate treatment goals, the resin is regenerated with sodium chloride (namely, the Cl ion) to displace the TOC from the resin sites and flush the removed TOC to waste. Depending on the water quality, periodic alkaline-brine cleanings may also be required to maintain peak efficiency and ensure long system life.

## Full-Scale Implementation

Following early pilot work done using a fixed bed ion exchange process in Florida by Baker, Lavinder, and Fu in Broward County (Baker, 1995), the first full-scale installation in Florida was built and commissioned in 1999 by Tonka Water (Tonka Equipment Co. at the time). Designed for Pratt & Whitney by CH2M, Thermax resin was selected for two 10-ft-diameter pressure vessels at a rated system flow of 1.5 mgd. In that application, CH2M selected an experienced ion exchange system manufacturer to ensure proper automation of the treatment and regeneration process critical for this industrial user using a nonproprietary ion exchange resin.

Following shortly after the start-up of the Pratt &Whitney installation in late 1999 was the commissioning of the first installation in the United States of a purely municipal fixed bed ion exchange system. Ultimately, two phases of organics removal at Pembroke Pines, Fla., would

be located downstream of lime softening (clarifiers/filters). The first phase of the project included four vessels, with a total rated flow of 4,200 gpm at a loading rate of 9.2 gal per minute per sq ft (gpm/ft$^2$). Brian Shields, Karl Kennedy, and other engineers at Calvin, Giordano, and Assoc. had evaluated the Thermax strong base Type-I anion exchange resin for TOC and color removal on a parallel track to CH2M's early work and were looking for a responsible system manufacturer to work with to bring the technology to full scale. They found a successful partner in Tonka Water to address nagging color problems for the city, and the treatment system has operated successfully for many years. Recent operational difficulties with the upstream lime softening clarifiers and filters necessitated a short-term shutdown of the ion exchange treatment trains to avoid damage to the ion exchange resin, but plans are to bring the system back online in the near future.

## Combined Cation and Anion Exchange

The next installation in Florida was for the Town of Lantana, which was commissioned in 2003. Designed by Mathews Consulting and GlobalTech Inc., the Lantana installation was the first system in the state to incorporate both anion exchange to remove color from filtered groundwater and cation exchange to reduce hardness. This highly flexible system enabled the town to treat hardness in two parallel softening vessels, followed by blending with filtered water and full-flow treatment through three parallel Organix™ vessels. With a total design flow of 4 mgd, partially softened, low-color, high-quality water is produced for the town.

## From Small to Large Scale

The two years from 2008-2010 would bring the start-up of two additional Tonka Water facilities that demonstrate the now-proven ability of packed bed anion exchange to scale from small to large systems: Palm Beach County Water Treatment Plant (WTP) No. 8, rated at 10 mgd, and Hamilton County, rated at 200,000 gal per day (gpd).

The system at Palm Beach County was commissioned in 2008 and would, at the time, be the largest installation of packed bed anion exchange in the state and the U.S. at 10 mgd, in a nearly 24-hour-per-day operational mode. An expansion was recently awarded in 2016 to bring the ion exchange-rated capacity to 30 mgd, a strong sign of the industry's acceptance and commitment to this unique technology. Palm Beach County's plant was designed by Camp Dresser & McKee, with seven 12-ft-diameter vessels. Downstream from lime softening, similar to the Pembroke Pines system, the anion exchange system was added to remove objectionable color from the softened, filtered water.

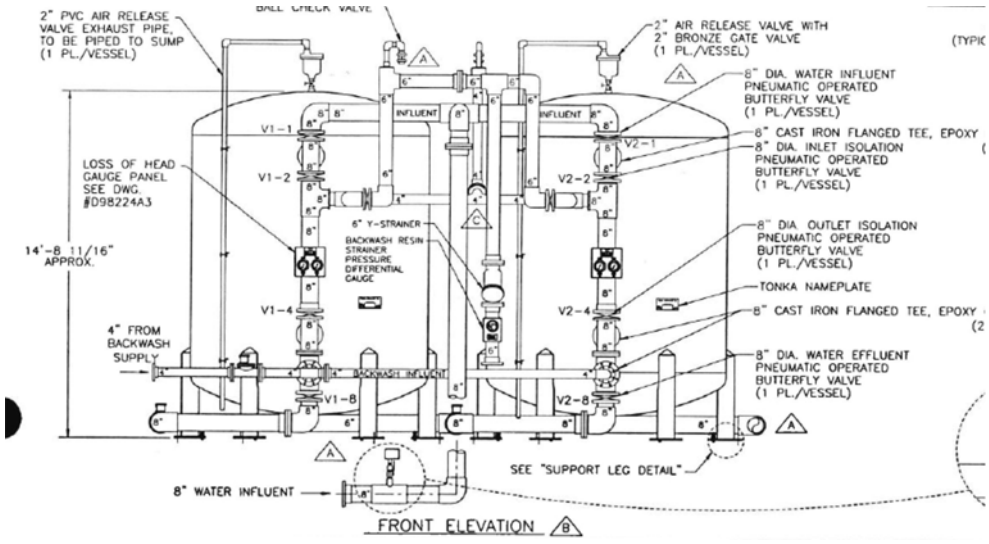


Figure 2. Pratt & Whitney Example Drawing

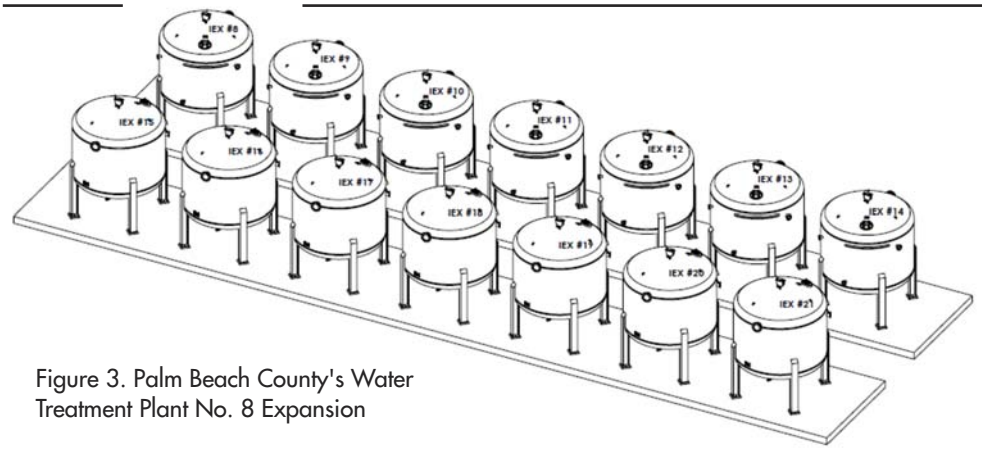

Figure 3. Palm Beach County's Water Treatment Plant No. 8 Expansion

Hamilton County's Organix system was brought online in 2010, downstream from a combined aeration/detention/filtration packaged plant for iron and manganese removal. Through piloting and evaluation, anion exchange resin manufacturers (Thermax, Purolite, and Dow) recommended that the incoming iron concentration be reduced to at least the secondary maximum contaminant level (SMCL) of 0.3 mg/L, if not 0.1 mg/L, prior to ion exchange for organics removal.

## Hybrid Anion Exchange/Biological Hydrogen Sulfide Removal

Building on the successes seen in the Town of Lantana's combined cation/anion treatment method, Hazen and Sawyer designed a system for the city of Arcadia that used a similar approach—softening and organics removal—adding another innovation with the use of a biological system for the removal of hydrogen sulfide ($H_2S$). Started up in 2013, the ion exchange system replaced traditional lime softening and enhanced coagulation for color removal, as sludge disposal grew to be a concern. Following extensive piloting by Dr. Audrey Levine at the University of South Florida (USF) in Tampa, the cultivation of biology within the ion exchange resin bed was developed at scale for removal of $H_2S$. Through this process, the organisms appropriate for oxidation of $H_2S$ are encouraged to develop, thereby lessening the need for additional treatment steps, such as aeration or filtration for $H_2S$ removal.

Commissioned the following year in 2014 was a fourth large Organix system for the state, namely the Markham WTP in Seminole County. Designed by AECOM, the installation treats nearly 7 mgd, with six 12-ft-diameter vessels. Continuing to push equipment improvements, both Arcadia and Markham included a lower-profile system, as compared to previous installations. Early system designs allowed for conservative headspace for

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resin expansion, and as experience was gained with the selected resin (Thermax) and resin loss was found to be minimal, a lower-cost profile solution was able to be provided.

## Continued Use

Anion exchange continues to be the most cost-effective and flexible means to reduce color and TOC in Florida groundwaters (Adib Amini, 2015). Throughout 2015 and 2016, Tonka Water would continue to install fixed bed ion exchange systems throughout the state, as three additional large projects were awarded: the expansion at Palm Beach County's WTP No. 8, Haines City WTP No.1, and Winter Springs WTP No.1.

Palm Beach County's WTP No. 8 will include the largest ion exchange system in the state (as well as the U.S.) upon its commissioning later in 2017. Designed by GlobalTech Inc. of Boca Raton, the expansion will increase the installed organics removal capacity by 200 percent, with an additional 14 vessels, and will give the county a reliable means to consistently reduce its TOC to less than 3 mg/L and color to less than 5 color units.

Designed by CPH Inc., the systems at Haines City WTP 1, with a rated capacity of 5.1 mgd, and Winter Springs WTP 1, with a rated capacity of 3.9 mgd, will build upon the experience of past hybrid biological/anion exchange systems for organics and $H_2S$ removal.

## Future Developments

As demonstrated with many successful municipal and industrial installations throughout Florida, packed bed anion exchange for organics removal is a proven and reliable process for the removal of TOC and color from its groundwaters. It's also a technology that exhibits opportunities for further advancement and new applications. As water resources become more and more limited, direct potable reuse (DPR) is being advanced as a means to stretch these limited resources. Organix can be easily applied to DPR treatment trains and was included as part of a 2013 pilot by Hazen and Sawyer at Hollywood, Fla., one of many DPR pilots completed in recent years (Charles W. Drake, 2016).

In addition to the ongoing evolution of packed bed ion exchange, a new technology that facilitates continuously regenerated ion exchange uses a multiport valve to enable constant regeneration. This reduces ion exchange resin volumes and brine consumption and provides a constant waste stream flow, all while reducing organics at efficiencies equal to conventional fixed bed ion exchange systems. This technology becomes all the more applicable, with reduced operational costs, as organics concentrations push higher and stricter effluent limits are desired.

## References


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