Suspended Ion Exchange: City of Tampa Demonstrates Exciting Alternative for Total Organic Carbon Removal

Melanie Pickett, Michael Gerdjikian, Crickett Luu, Chuck Weber, Antony Gibson, Vincent Hart, and Tyler Smith

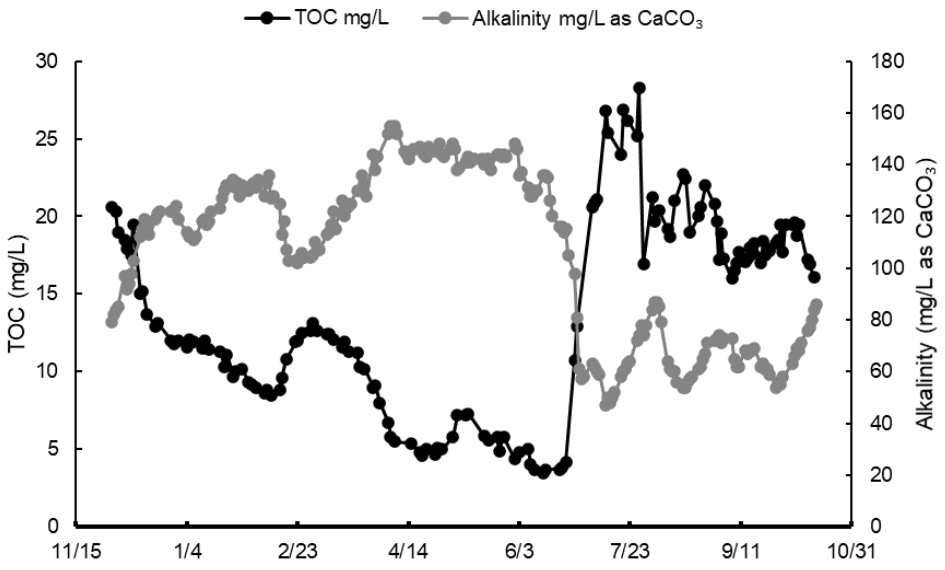

Figure 1. The facility's raw water seasonal variability during the pilot (data from Nov. 30, 2020, to Oct. 15, 2021)

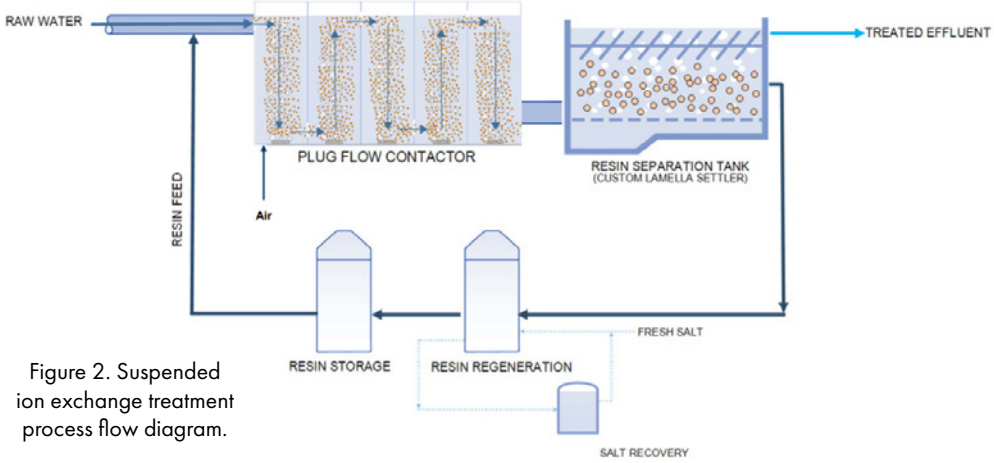

Figure 2. Suspended ion exchange treatment process flow diagram.

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The City of Tampa Water Department (city) owns and operates the 120-mil-gal-per-day (mgd) David L. Tippin Water Treatment Facility (facility) located in Tampa. The facility's primary source of water, the Hillsborough River, experiences high seasonal variability; in particular, raw water total organic carbon (TOC) ranging from 3 to 30 mg/L (Figure 1).

Maintaining high-quality finished water under the wide range of influent water quality conditions throughout the year is challenging. Given the facility's existing water quality challenges, need for expansion, and extensive chemical use and solids generation, a detailed alternative analysis of treatment options was completed as part of master planning efforts.

A recently completed pilot study demonstrates a new suspended ion exchange (SIX®) process, which is the first of its kind in the United States, as a promising new technology to help overcome the city's challenges.

The facility currently employs an enhanced coagulation (EC) treatment method (including

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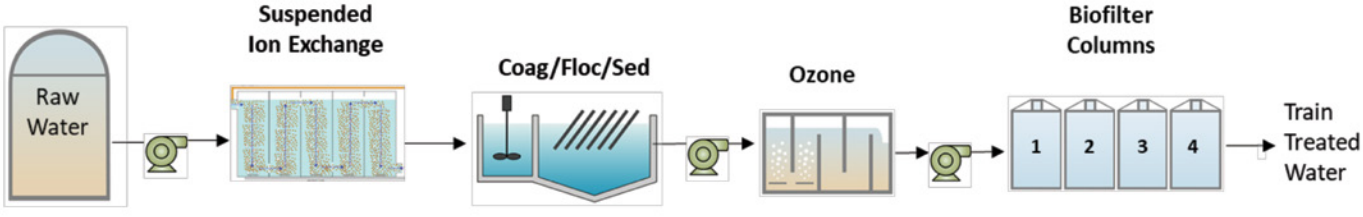

Figure 3. Tampa pilot treatment train.

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high doses of coagulant and acid addition), resulting in high chemical usage, aggressive water quality in specific unit processes, and high solids production. Alternatives were evaluated to optimize or replace the facility's current EC treatment approach and corresponding solids handling processes, while still achieving or improving the city's water quality goals.

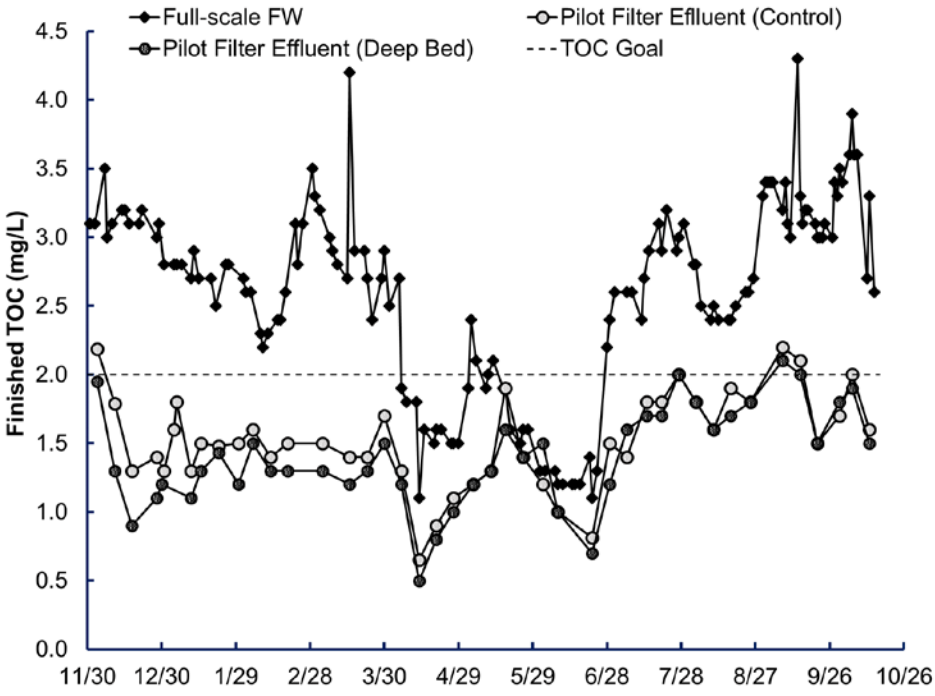

Figure 4. Full-scale and pilot filter finished total organic carbon (data from Nov. 30, 2020, to Oct. 15, 2021)

Table 1. Average Suspended Ion Exchange Anion Percent Removal Performance

	Sulfate	UVA	TOC	Alkalinity	Bromide	Chloride	Apparent Color
Average Change	89%	54%	49%	48%	17%	+340%	20%

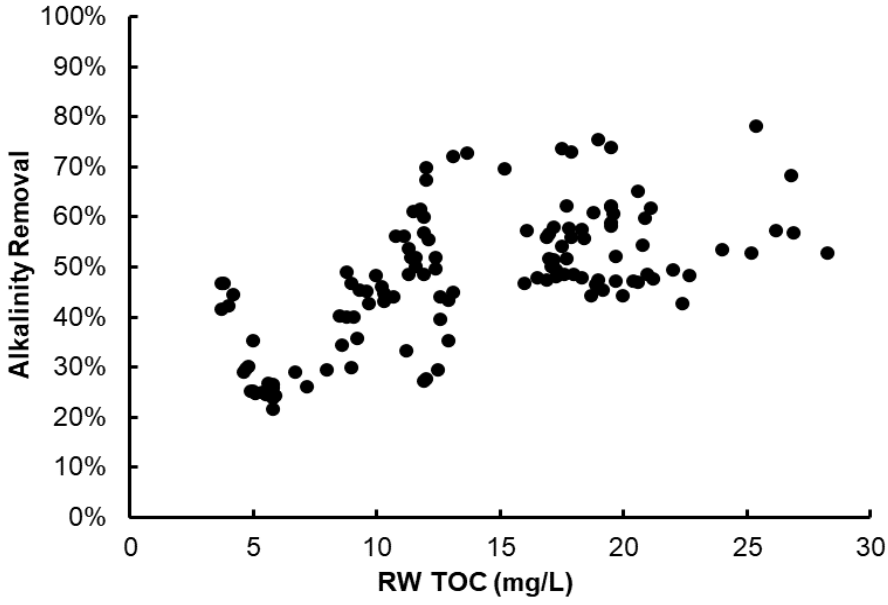

Figure 5. Suspended ion exchange pilot alkalinity removal versus raw water total organic carbon.

New Technology: Suspended Ion Exchange

As part of the alternatives assessment, Carollo and Ramboll worked together to perform a multiseason pilot study to test SIX, an exciting alternative to traditional magnetic or fixed-bed ion exchange. Initially developed in the Netherlands, the SIX technology has had much success with multiple full-scale plants in Europe.

The technology has several advantages over the other available ion exchange technologies. Its plug flow reactor design utilizes a strong base anion exchange resin that allows for faster regeneration and reduced salt concentrations. The resin is dosed into the raw water flow just before it flows through the contactor, where it's kept in suspension utilizing air fluidization. Since the resin and raw water flow together, both have the same hydraulic retention, or residence time, allowing for a more-uniform distribution of resin and resin functional group sites for the exchange process. After it's collected, the resin is regenerated in a batch process with a salt brine solution (NaCl). Figure 2 presents an overview of the SIX process.

Suspended Ion Exchange Pilot Plant in Tampa

Pilot-scale testing generated scalable performance data and an understanding of SIX's impact on downstream processes. The overall pilot train incorporated SIX, a coagulation/ flocculation/ sedimentation basin, an ozone contactor, and four biofilter columns. The four filter columns were operated in parallel, each with different filter configurations to optimize filtration; one of these is a control filter with the same media and configuration as the full-scale plant. Data from the two best-performing filters are discussed herein.

A variety of potential impacts of the SIX process on the downstream processes were evaluated, including a reduction in chemical use (coagulant, polymer, acid, base, etc.), decrease in solids production and handling, changes in filter dynamics (headloss, biological growth, constituent removal), changes to process water alkalinity, and changes in ozone demand and oxidation, among others. Figure 3 shows a simplified version of the pilot-scale process train.

Pilot Results and Conclusions

Overall, water quality was reliably improved using the SIX process, which complements the coagulation process regarding organics removal.

The pilot consistently achieved the finished water quality goal of below 2 mg/L TOC, even with variable raw water quality (Figure 4). Current full-scale chemical usage was significantly reduced at the pilot; however, significant salt usage was also required to operate SIX. With better water quality at the downstream processes, ozone demand was also reduced, and significantly higher loading rates and subsequent unit filter run volumes (UFRV) were achieved by the pilot filters.

Suspended Ion Exchange Performance

A continuous ion exchange process, SIX utilizes a nonproprietary strong base anion (SBA) exchange resin with multiple manufacturers. The selectivity of nonproprietary anion exchange resin for different anions is typically as follows:

$$SO_4^{2-} > TOC > NO_3^- > Cl^- > HCO_3^- > OH^-$$

This trend was generally observed with the SIX pilot. The data in Table 1 show that sulfate removal is relatively high, at 89 percent. The resin has a high affinity for sulfate (relative to bicarbonate). Chloride content increases in the treated water due to ion exchange between target and counter anions; chloride increase was highest when raw water anion concentration was highest. Throughout the pilot, the finished-water TOC goal of <2 mg/L was consistently achieved with influent raw water TOC as high as 28 mg/L.

With SIX salt use, there were higher chloride results in the finished water. Salt use was found to be greater than double the salt use of magnetic ion exchange (MIEX®)—an alternative fluidized bed ion exchange technology for removal of dissolved organics—due to the regeneration frequency of SIX and the nonselective removal of anions. Further techniques are being investigated for salt optimization. Resin fouling was not observed at the pilot scale throughout the 10-and-a-half-month test period.

At first a concern, the SIX alkalinity removal was instead observed to be a tool for monitoring performance and managing operations. Depending on seasonal raw water alkalinity, SIX could be operated to achieve desired effects based on the effluent alkalinity. This is a significant differentiating factor between the SIX process and MIEX process, where the resin has high TOC affinity, but a lower bicarbonate affinity (Figure 5).

Coagulation Performance

A summary of coagulation performance is shown in Table 2. With the SIX alkalinity removal, pH depression for coagulation was achieved with lower coagulant doses and eliminated the need for sulfuric acid (currently utilized most of the year at full scale) to achieve the same or better TOC removal (Figure 6). Pilot results also demonstrated the viability of eliminating the need for lime, which is routinely used at the facility. Coagulant (ferric sulfate) usage was reduced on average by 64 percent, along with a 59 percent reduction in floc-aid polymer usage. In addition to chemical cost savings, any reduction in coagulant demand will translate directly to a proportional decrease in sludge production, leading to additional solids handling cost savings.

Table 2. Average Coagulation Performance of the Pilot Versus Full Scale

	SIX Pilot	Full Scale
Ferric Sulfate Dose (mg/L)	45	124
Sulfuric Acid Dose (mg/L)	Not used	61
Coagulation pH	5.4	4.7
TOC removal (%)	60%	66%

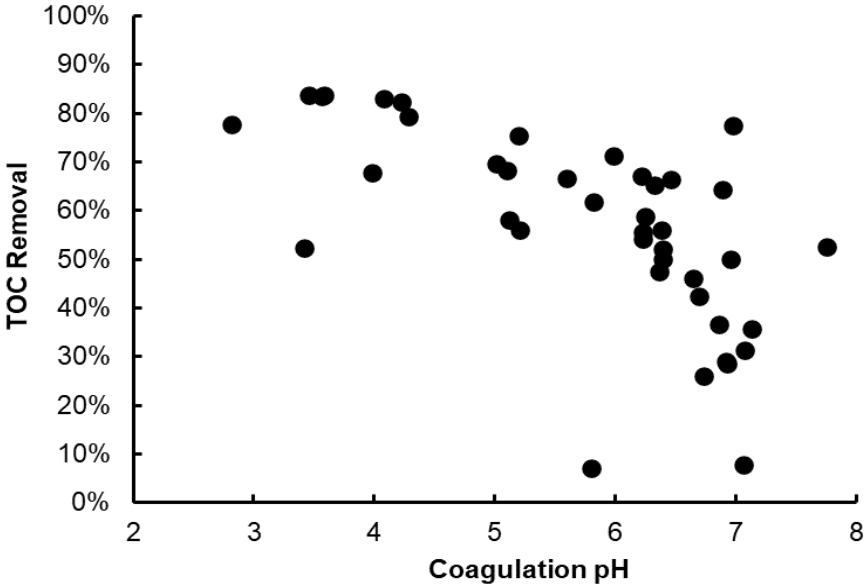

Figure 6. Pilot coagulation performance: percent total organic carbon removal versus coagulation pH.

Table 3. Suspended Ion Exchange Pilot and Full-Scale Ozone Performance

	SIX	Full Scale
Applied Ozone Dose (mg/L)	2.0	2.9
Pre-Ozone TOC (mg/L)	2.2	3.6

Table 4. Overview of Pilot Filter Media Configuration and Operation

	Filter 1 Existing Control Filter	Filter 2 New Deep Bed Filter
GAC depth (in.)	22	63
Sand depth (in.)	12	9
ES, GAC (mm)	1.05	1.40
ES, sand (mm)	0.5	0.6
Loading rates tested (gpm/sq ft)	3.25-8.0	6.0-10.0
Allowable Headloss (ft)	6	12

Ozone Performance

Due to the successful TOC reduction through

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SIX and subsequent coagulation, flocculation, and sedimentation, the TOC loading onto the pilot intermediate ozone was lower than is typical at full scale (Table 3). This was found to be especially true during the period of high raw water TOC. With lower pre ozone TOC, the ozone dose was also reduced, on average, by 31 percent.

Biofilters Performance

Different filter configurations were tested during this pilot. A control filter consisted of media pulled directly from an existing full-scale filter and loaded in the same configuration (Table 4). An alternative "deep bed" filter was tested for future design of new filters at the facility. Through this piloting effort, it was found that when both the SIX and coagulation processes are optimized, filter performance is greatly improved when compared to the full-scale filter performance, with UFRV increasing by as much as a factor of 4. This is true even when compared to the "control" pilot filter with the same configuration as the full-scale filters (Figure 7).

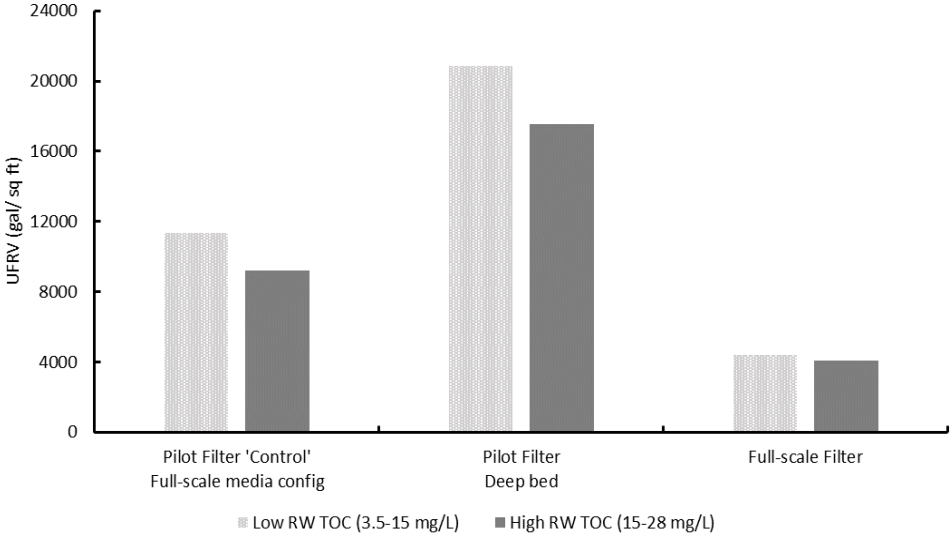

Figure 7. Average unit filter run volumes: full-scale and suspended ion exchange pilot comparison.

Conclusions

This SIX piloting has characterized improved treatment performance over a wide range of raw water quality conditions, confirming that a SIX-based treatment process can reliably and continuously produce treated water that meets all of the city's finished water quality goals, including finished water TOC less than 2 mg/L. Furthermore, the piloting established preliminary operating criteria and a range of chemical doses and waste streams, enabling full-scale design criteria and analysis of life cycle costs.