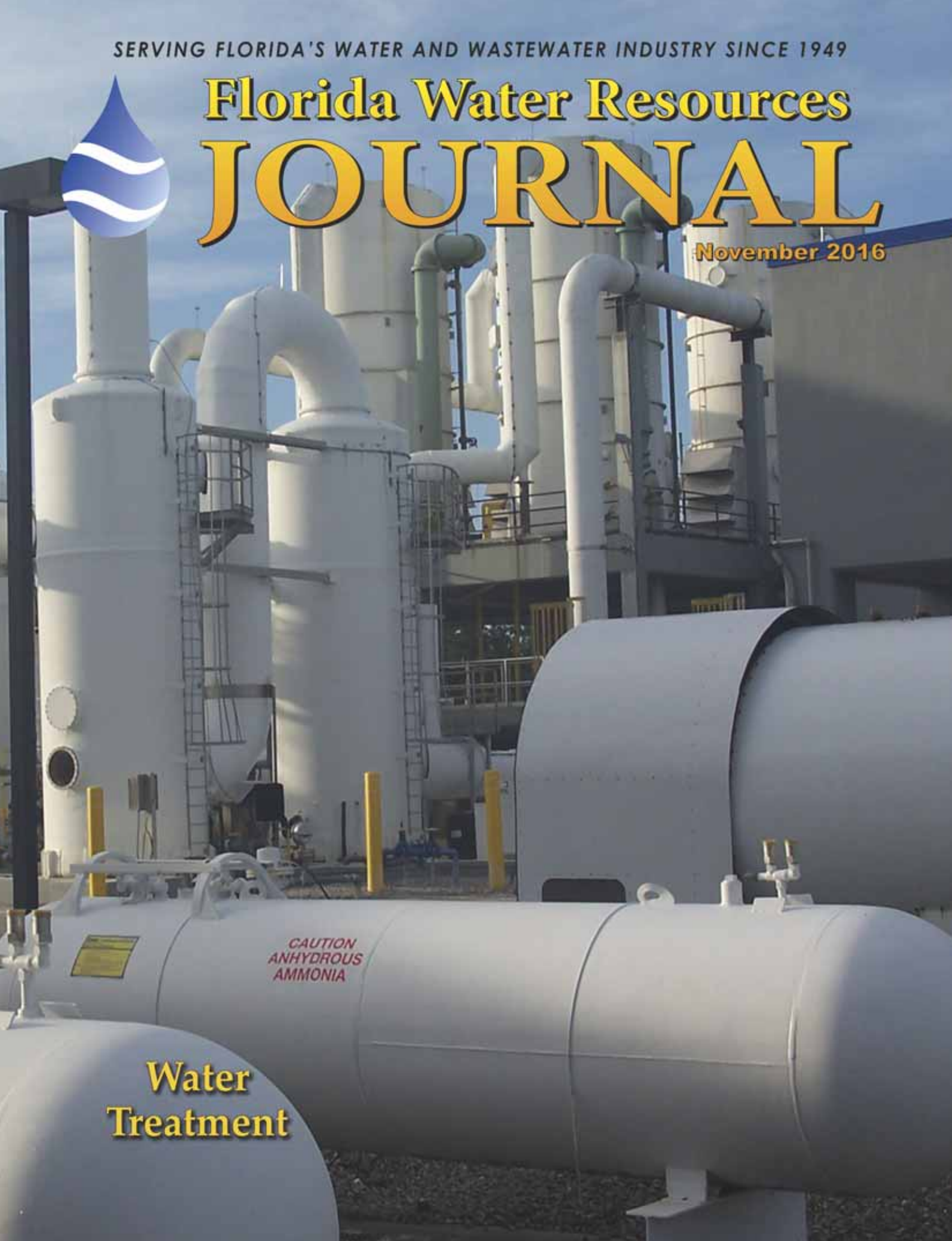


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**Water
Treatment**

Anion Exchange Treatment for Color Removal: The Story of a Utility That Experienced Finished Water Foul Odor and Eliminated It

Renuka Mohammed-Bajnath, Jeffrey Pinter, GJ Schers, and André McBarnette

The Town of Davie (town) operates a water treatment plant (WTP) with a rated capacity of 4 mil gal per day (mgd), but operates generally between 2 and 3 mgd. This facility is commonly referred to as System 3. Using the Biscayne Aquifer as the raw water source, the treatment process includes lime softening, media filtration, and chlorine disinfection. Hydrated lime and polymer (Praestol 2530 TR) are dosed to the softener influent to remove hardness and alkalinity, and to improve the softened water

turbidity. The town also adds phosphoric acid (Carus Aquadene SK-7641) for corrosion control in the distribution system and hydrofluosilicic acid (Dumont HFS 2300) for dental hygiene. A simplified flow diagram is included in Figure 1.

The raw water contains naturally occurring elevated levels of free ammonia and color that have been reported to be as high as 2.5 mg/L and 50 platinum-cobalt units (PCUs), respectively. There is some variation in levels of hardness, alkalinity, color, and

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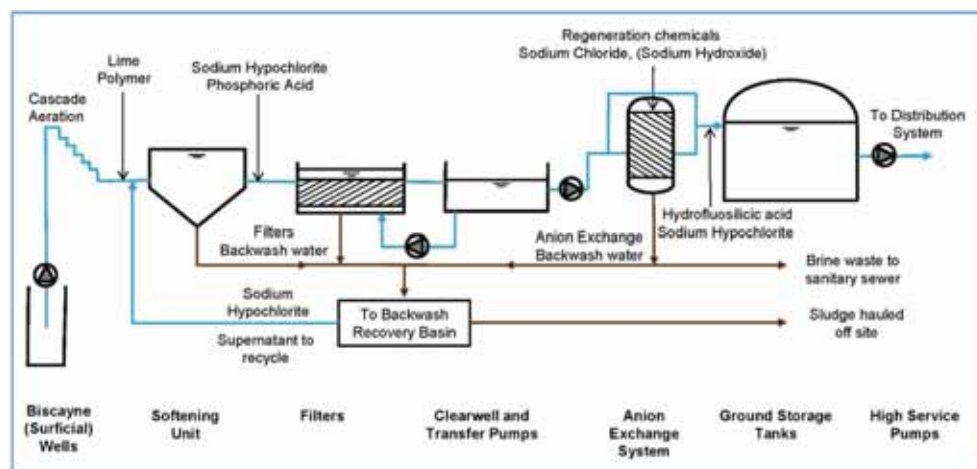


Figure 1. Schematic Diagram of Town of Davie System 3 Water Treatment Plant

ammonia among the production wells, and the limits listed are considered worst-case. Some free ammonia combines with chlorine to form chloramines downstream of the softener, and some free ammonia remains in the water. The main water quality data from the WTP are summarized in Table 1.

In 2008, an anion exchange (IEX) treatment system was installed at the WTP, downstream of the filters, to remove objectionable color from the filtered water. The system consists of pressurized vessels filled with macro-porous Type-1 strong-base anion resin for color removal and ancillary facilities for resin regeneration.

Ancillary facilities include brine storage tanks, recirculation piping and pumps, brine dissolution system, waste tanks, and supporting electrical and instrumentation systems. Since installation in 2008, the system has been operating successfully; however, since 2014, objectionable foul odors have been detected in the finished water, evident by customer complaints. Initial investigations by the town's staff revealed that the odor was of a "musty and fishy" nature and originated from the IEX system.

Several changes were implemented at the WTP in 2014, including replacement of IEX resin, start of phosphate-based corrosion inhibitor dosing, and conversion of onsite hypochlorite generation to bulk sodium hypochlorite. Furthermore, in mid-2014, considerable biological growth was observed in

Table 1. Main Water Quality Data at Town of Davie System 3 Water Treatment Plant (average values, year 2015)

Parameters	Raw Water	Settled Water	Finished Water
pH, s.u.	7.5	9.6	9.4
Hardness, mg/L as CaCO ₃	320	90	90
Alkalinity, mg/L as CaCO ₃	260	70	70
Color, p.c.u.	50	25	<5
Ammonia, mg/L as NH ₃	2.5	1.5	1.0
Total Organic Carbon, mg/L	14.0	11.0	2.5 (10-11 when IEX is not operational)

IEX vessels and subsequently analyzed. The analysis revealed the presence of nitrifying and denitrifying bacteria, as well as sulfur-reducing bacteria. Following this observation, the town performed additional chemical resin cleans, with both sodium hydroxide and sodium hypochlorite, that caused some concerns on whether the resin was permanently damaged or not.

Because of the simultaneous WTP changes, no one particular cause could be identified for the sudden presence of foul odor in the finished water. As such, the town developed a systematic approach in an attempt to identify the cause of the odor. The initial phase focused on obtaining and understanding best management practices at other utilities that operate IEX systems, telephone conversations with several strong-base anion resin suppliers, and discussions with IEX system integrators. Also, extensive operational and performance data were reviewed from the town's IEX system, including water quality data. The follow-up phase focused on bench tests performed with new and existing (biofouled) resin under different feed water conditions to test the odor release pathway hypothesis. Subsequent to the bench tests, a temporary carbon dioxide (CO₂) dosing system was installed, the phosphate-based corrosion inhibitor dosing point was relocated to downstream of the IEX system, and the system was recommissioned. Extensive operational and water quality data were collected during this phase to confirm the odor release pathway hypothesis and to optimize the IEX and other treatment systems.

This article presents the experiences of a utility using strong-base anion resin for color removal from groundwater, which is a relatively new type of treatment in Florida. In this particular case, it was revealed that certain feed-water conditions can cause a foul odor in the treated water. Other lessons

learned were also obtained from site visits and conversations with suppliers and other utilities utilizing IEX. Extensive water quality data were collected during the bench tests

and full-scale commissioning to verify odor release pathway hypothesis, and to optimize the IEX system operations.

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Table 2. Summary of Information From Utilities and Suppliers

Parameters	Town of Davie, System 3	Palm Beach County, System 8	Pembroke Pines (-)	Supplier(s) Recommended Value
IEX System				
Capacity, mgd	4.0	10.0	12.0	-
Number of Vessels, -	3	7	8	-
Diameter Vessels, ft	12	12	12	12 (standard)
Resin Depth, in.	36	36	36	24 or above
System Supplier, Resin	Tonka, Thermax A-72MP			-
Flow through IEX, percent of total	100%	40-50% (Future 100%)	50%-60%	-
IEX Influent/Effluent Quality				
Color (Raw Water), p.c.u.	50	30	45	-
Color (Effluent), p.c.u.	<5	<5	<10	-
pH, s.u.	9.6	8.7	8.6	<8.5
Hardness, mg/L CaCO ₃	70	80	60	-
Alkalinity, mg/L CaCO ₃	60	60	30	-
Chloramine, mg/L	4-5	2-4	1-2	<5 mg/L No free Cl ₂
Ammonia, mg/L	1.0	<0.1	<0.1	-
Regeneration, Rinse Procedures				
Backwash Rate, gpm/ft ²	4-5	5-7	3	2-4
Air Scour assist BW, Yes/No	No	Yes	No	Yes (based on lessons learned)
Brine Solution strength for regeneration, -	Saturated solution (13.5%) as recommended by Tonka and Thermax			Saturated (13.5%)
Slow/Fast Rinse, -	Done as recommended by Tonka			
Alkaline-Brine Squeeze, -	Done recently	-	-	To be limited
Sodium Hypochl. Soak, -	Done recently	-	-	To be limited



Figure 2. Existing IEX System at the Town of Davie System 3 Water Treatment Plant

IEX System of the Town and Other Utilities

The town's IEX system consists of three carbon steel vessels, with an internal diameter of 12 ft. The design flow rate is 2,800 gal per minute (gpm) or 4 mgd, which equates to a surface water loading rate of 8.26 gpm per sq ft (gpm/ft²)⁽¹⁾. Each vessel contains 36 in. of Thermax A-72MP anion exchange resin sup-

ported by 3 in. of 0.80-1.20 mm silica sand and 12 in. of graded gravel. This resin has National Sanitation Foundation (NSF) 61 certification.

The system also contains a brine tank, brine pumps, and a brine dilution skid to dilute and feed brine and rinse waters into each of the vessels for resin regeneration. The waste flow of the brine and rinse cycles is discharged to the rinse waste tanks and subsequently bled to the sanitary sewer. Typically, the resin is backwashed prior to a brine regeneration for suspended solids removal

through manipulation of isolation valves to reverse the flow through a vessel. The waste backwash water is discharged through the same pipe as the waste flow from the brine and rinse cycles; however, it is discharged through manipulation of isolation valves into the backwash recovery basin for possible recovery to the head of the plant. Some photos of the system are included in Figure 2.

Over time, calcium carbonate and calcium sulfate buildup were observed by the town on the resin; this made the resin heavier and affected its performance, which was evident in shorter run times. The town also experienced some operational challenges that inhibited performance. As a result, the resin was replaced in mid-2014 with new Thermax resin, with the same specifications as the original resin.

Since early 2015, reports of foul odor originating from the IEX system have increased, and by mid-2015, the town executed chemical cleans, in addition to the brine regeneration. In conjunction with Thermax, the town performed a caustic soda squeeze (brine with sodium hydroxide to bring pH to 13.5) and a sodium hypochlorite soak clean (brine with 1 percent chlorine solution). The IEX system was restarted in July 2015, but the foul odor returned quickly and the system was turned off. As will be discussed further, the system remained offline during the period of investigations, bench testing, and modifications, and was only recommissioned in December 2015. Since that time, the IEX system has been online continuously and has operated successfully.

In mid-2015, Thermax representatives visited the WTP site for an inspection of the system and obtained a resin sample. The results indicated the presence of foul odor and organic fouling on multiple resin samples and reduction in dry-weight capacity and moisture content when compared to the specifications of virgin resin; however, the physical appearance, moisture content, and size were within specification. The total anion exchange capacity had dropped slightly below specification, evident in short run times.

The town proceeded to perform site visits to other utilities in southeast Florida that operate IEX systems in an attempt to obtain information and lessons learned from treating raw water with similar elevated levels of color and free ammonia. A summary of the findings from site visits to other anion exchange systems include Palm Beach County (PBC) System 8 WTP and the City of Pembroke Pines (CPP) WTP. Suppliers are listed in Table 2.

The treatment process and performance of the other utilities are similar to the town's, with some distinct differences. For instance, PBC recarbonizes softened water and reduces the pH with CO₂ prior to filters. The PBC also combines all free ammonia to chloramine with sodium hypochlorite prior to the filters and doses of additional sodium hypochlorite and ammonia downstream of the IEX system to maintain a combined chlorine residual of 4 mg/L. Similarly, CPP combines all free ammonia to chloramine with chlorine gas prior to the filters, creates a pH drop with the (acidic) chlorine gas upstream of the IEX system, and adds both chlorine gas and ammonia at the end of the process.

The visited utilities provided improvements over the years based on lessons learned. For instance, PBC discontinued IEX backwash waste recycling to the head of the WTP to reduce the sudden increase in trihalomethanes (THMs) formation, provided more alkaline-brine regeneration to minimize accumulation of foulants on the resin, and added air sparging grids to assist with resin breakup during regeneration, thus improving effectiveness and decreasing regeneration time. Other lessons learned from utilities included reducing vessel height from 12 ft to 8 ft to reduce brine consumption and waste volumes, increasing the volume of the waste rinse tasks in the event that vessels need to be regenerated in series, and adding online water quality monitoring systems to provide a live feedback of how the IEX system was performing.

System integrators and resin suppliers were also contacted to discuss issues surrounding the foul odor from the IEX treatment system, including actual suppliers of

the town (e.g., Tonka and Thermax); other parties contacted included Hungerford & Terry, DOW, Resin Tech, and Purolite. Discussions among these suppliers were similar and all focused on the high pH of the IEX influent, which can affect the basic structure of the macroporous strong-base anion resin. Based on this preliminary work, it was believed that the predominant pathway of release of the foul odor is the high pH of the IEX influent water.

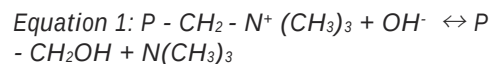
There was evidence from prior testing that the resin had lost its dry-weight capacity and treatment capacity through “knocking off functional groups from the resin.” A process was recommended to reduce the pH of the IEX influent water to around 8.5–8.8, with CO₂ through the installation of a temporary storage CO₂ system, relocation of the phosphate-based corrosion inhibitor dosing point until after the IEX treatment system, and addition of an online dual-channel ammonia analyzer to monitor free ammonia, total ammonia, monochloramine, and total chlorine in the IEX influent and IEX effluent. Prior to the installation of the CO₂ system, a series of short-term bench tests were performed.

Trimethylamines Odor

Based on feedback from resin suppliers, the fishy odor is believed to be trimethylamines (TMA), with a very low odor threshold of 5 parts per billion (ppb). Wikipedia⁽²⁾ describes TMA as an organic compound, with the formula N(CH₃)₃ (see molecule depiction in graphic), and is colorless, hygroscopic, and flammable. It has a strong fish-like odor in low concentrations and an

ammonia-like odor at higher concentrations. It is a gas at room temperature. In general, TMA is known as a product of the decomposition of plants and animals, and is also used in the resin manufacturing process.

As referenced, the building structure of macroporous Type-1 strong-base anion exchange resin is cross-linked polystyrene (P) with TMA as the functional group. The characterization Type 1 stands for a quaternized amine product made by the reaction of trimethylamine with the copolymer after chloromethylation. Type 1 is the most strongly basic functional group available in the market and has the greatest affinity for the weak acids, such as silicic and carbonic. The TMA can be released from the resin at very low levels due to slight de-amination of the resin by the Hofmann's reaction at higher pH values, as per equation 1⁽³⁾:



Amines are released due to the hydroxyl ions (OH⁻) in the water seeking to “attract” a proton (H⁺) from the resin, thereby breaking other molecules' structure bonds. The Hoffman reaction is the primary degradation mechanism for Type-1 anion exchange resins. High temperatures and pH values will accelerate the rate of resin de-amination.

Bench Testing

A series of short-term bench tests were conducted with existing and new IEX resin at the town's System 3 WTP laboratory. The specific objectives of the study were to understand the impacts of pH on the fishy odor released in the treated water and to verify the performance of the existing resin compared to new resin. The bench-test configuration and conditions are included in Table 3, and the photo provides a depiction of the bench-test setup.

The effluent water of the baseline operation (pH 9.6) started to have a fishy odor within a couple of hundred bed volumes (BVs) of operation, and continued to have low to medium odor for the entire duration of the test (Figure 3). The effluents of the tests conducted at pH 9.1 and pH 9.2 also appeared to have low to medium odor; however, the frequency of such low-medium odor samples were not as high as observed in the effluents of the pH 9.6 test. The effluent samples for the tests conducted at pH 8.2 and pH 8.8 remained predominantly odorless

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Table 3. Bench-Test Configuration and Conditions

Parameter	unit	Value
Column Diameter	mm	15
Packed-bed Length	cm	21.6
Packed-bed Volume	mL	38
Flow Rate	mL/min	21.5
Empty Bed Contact Time	min	1.8
Test Conditions	Existing/New Resin, Feed Water pH and Run Time in Bed Volume (BV)	Existing Resin 8.2 (3,300 BV) 8.8 (6,310 BV) 9.0 (4,540 BV) 9.1 (1,190 BV) 9.2 (1,190 BV) 9.6 (1,670 BV) New Resin 9.6 (1,090 BV)



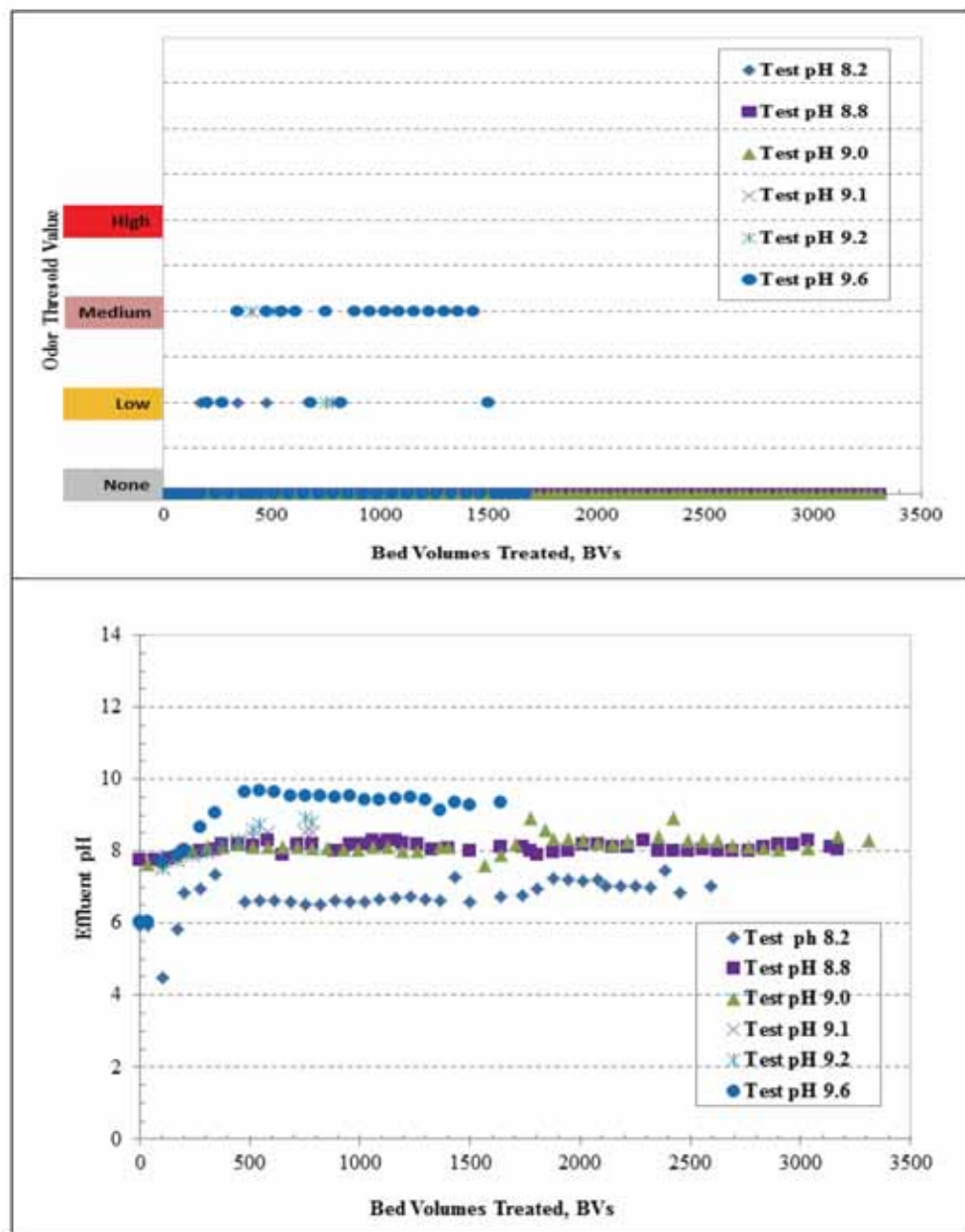
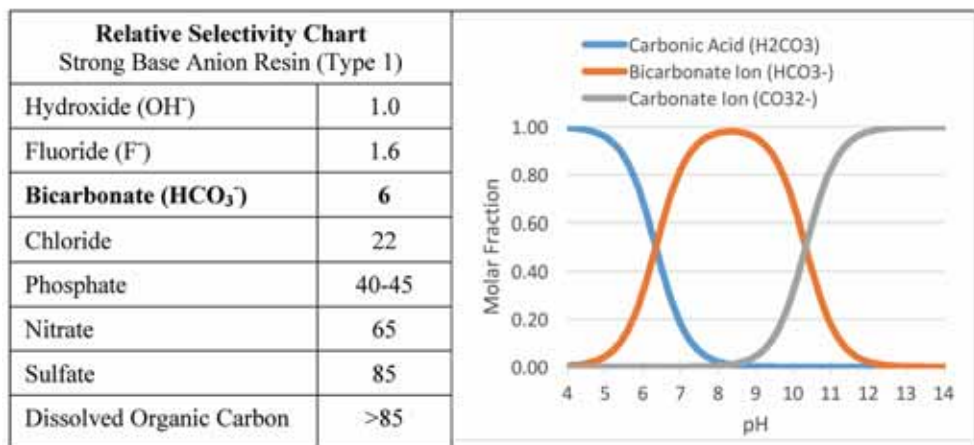


Figure 3. Odor and pH in the IEX Bench Test Influent/Effluent Samples

Table 4. Strong-Base Anion Exchange Resin Relative Selectivity Chart (left) and



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during the entire duration of the tests. The fishy odor noted in a few samples might be due to the judgment error of the observer or background odor.

The pH values of the effluent samples of different test conditions are also presented in Figure 3. The data suggests that, initially, a slight pH drop occurs across the anion exchange resin, evident from effluent pH values being lower than influent pH values. The total organic carbon (TOC) and color breakthrough were observed after approximately 2000-2500 BVs, which is lower than observed in the full-scale plant. Based on discussions with the system integrator, it is believed that this is due to the Empty Bed Contact Time (EBCT) being lower in the bench-test setup, as compared to the full-scale plant.

Based on the findings from the bench tests, it was concluded that the operation of the IEX plant at a reduced pH (between 8.5 and 8.8) may eliminate the fishy odor in the treated water of the full-scale plant, without impacting color removal. Additional testing and monitoring at the full-scale plant was recommended to understand potential implications of the pH drop in the plant's distribution system after the installation of the temporary CO₂ system.

Why Does the pH Initially Drop During a Run?

The IEX resins, when placed in a solution, reach an equilibrium state between ions in the solution and ions on the resin. From this equilibrium state, selectivity coefficients (equilibrium constants), can be defined based on the ratios of ions in solution versus ions on the resin. Among others, selectivity is determined by ion valence, molecular weight, concentration, and temperature. Table 4 includes the relative selectivity chart for competing anions and, in this particular case, the selectivity of the bicarbonate ion is important⁽⁴⁾. Alkalinity levels in the IEX feed water are between 60 and 80 mg/L, while all alkalinity is in the bicarbonate form at the recarbonized water pH levels between 8 and 9. Therefore, bicarbonate levels in the influent are relatively high and it can be expected that in the initial phases, bicarbonate gets exchanged on the resin until an equilibrium is reached with the ion concentration in the water. Over time, the bicarbonate ions associated with the resin will be exchanged with other anions with higher selectivity to the resin, like organics, such as dissolved organic carbon (DOC) and sulfate.

Calcium and carbonate/bicarbonate are in equilibrium in water, as explained by the calcium-carbonate equilibrium equation frequently used in the water industry (equation 2). At the town's pH values in the IEX influent, almost all alkalinity is in the bicarbonate form (equation 3). During the initial ion exchange process, the bicarbonate (HCO_3^- and CO_3^{2-}) ions will be exchanged on the resin, leaving the calcium ions (Ca^{2+}) unassociated in the water. The Ca^{2+} will then absorb hydroxide (OH^-) from the water and will leave free protons (H^+) behind in the water causing the pH drop.

Equation 2: $\text{CaCO}_3 (\text{s}) \leftrightarrow \text{Ca}^{2+} + \text{CO}_3^{2-} (\text{aq})$

Equation 3: $\text{CO}_3^{2-} + \text{H}_2\text{O} \leftrightarrow \text{HCO}_3^- + \text{OH}^-$
($\text{pK}_\text{a}=10.3$)

Temporary Carbon Dioxide Dosing System

As a result of the initial investigations and confirmed by the bench tests, a temporary CO_2 dosing system was installed downstream of the filters to reduce the pH of the IEX feed water to between 8.5 and 8.8. Figure 4 shows photos from the CO_2 storage tank and (direct gas) dosing skid. Additionally, the phosphate-based corrosion inhibitor dosing point was relocated downstream of the IEX treatment system, and an online dual-channel ammonia analyzer was added to monitor levels of free ammonia, total ammonia, monochloramine, and total chlorine in the IEX influent and IEX effluent.

The Rothberg Tamburini Windsor

(RTW) model⁽⁵⁾ for corrosion control and process treatment chemicals was then used to calculate the CO_2 dose required to achieve an IEX feed water pH of around 8.5. Softened and filtered water quality parameters were taken from the WTP's available monthly operation reports (MOR) from January through June 2015. The average calculated CO_2 dose was 10.8 mg/L, and, dependent upon actual softened water pH, alkalinity, and hardness, the dose can range from anywhere between 1 to 20 mg/L, which is dependent upon raw water quality-based actual wells operated and softener performance. The town's target finished water pH in relation to corrosion control is around 8.5.

Recommissioning of the IEX System

After the plant modifications were completed, the IEX system was recommissioned. During the recommissioning phase, which stretched over three runs from Dec. 12, 2015, until Feb. 17, 2016, the town collected extensive operational data from the IEX, chemical systems, and water quality data, as summarized in Table 5. The data were used to verify an odor release pathway hypothesis, and to optimize the IEX system and treatment processes operations.

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Table 5. Data Collected During the Recommissioning Phase

Settled Water Quality	pH and Chlorine Profiling WTP	IEX System Operational Data	Chemical Systems Operational Data	Finished Water Quality
pH Flow Turbidity Alkalinity - m - p Hardness - Total - Ca - Mg Color Chlorine - total - free Free ammonia	For each location: Settled water Re-carbonized water IEX influent IEX effluent GST fill line (finished water): - total - free - ammonia	For each vessel: - Flow - Volume - Color - Odor - pH - Alkalinity - Before - After - pH - Before - After - Pressure - Before - After	Lime - Feed rate - Pressure - Concentration Chlorine - Feed rate - Pressure - Concentration Phosphate - Feed rate - Pressure - Concentration Fluoride - Feed rate - Pressure - Concentration	Turbidity Alkalinity - m - p Hardness - total - Ca - Mg Color pH Phosphate Conductivity Chlorine - Total - Free Free ammonia



Figure 4. Carbon Dioxide Storage Tank and Dissolution Skid During Construction

Overall Plant Performance

The overall plant performance was monitored over time to identify concerns and opportunities for improvement. One of the main challenges of the WTP is to maintain a consistent pH profile through the process, evident in the graphics included in Figure 5. The graphic on the left presents the pH value in the softener effluent, which varies in general between 8.9 and 10.6, with some excursions outside that band; the same graphic presents the alkalinity and hardness values in the softener effluent and, as expected, these values vary quite considerably as well. The graphic on the right presents the pH values before and after recarbonation. The values after recarbonation are relevant for this study as they represent the pH values in the IEX influent and vary between 7.9 and 9.2.

Run 1 (Dec. 12-20, 2015)

During Run 1, the town used a target pH in the IEX influent of 8.8. In cooperation with the equipment supplier, the new temporary CO₂ dosing skid was set up to maintain this. Several variables at the dosing skid had to be adjusted to achieve a more stable influent pH profile over time. During Run 1, most of the filtered water was processed through IEX Vessel No. 1, with the remainder processed in Vessel No. 2 and No. 3. The values of color and odor in the IEX effluent of Vessel No. 1 are depicted in the graphic on the left in Figure 6, whereas the pH profiles in the influent and effluent of all vessels are depicted in the graphic on the right. This run was aborted abruptly after 589 BVs due to the presence of odor in a single effluent sample of Vessel No. 1.

Further observations of the data revealed that:

- ◆ The pH in the influent was varying extensively around the pH set point of 8.8 due to setup and commissioning issues with the carbon dioxide skid.
- ◆ Prior to the presence of odor in the sample, the pH in the IEX influent had been between 9.0 and 9.2 over the prior 24-hour period.
- ◆ The pH in the effluent was lower than in the influent, with a reducing gap over time.

It was observed that the town's personnel were still relatively sensitive towards recurring odor in the finished water, evident in the abrupt abortion of Run 1. Also, the town was concerned about the pH drop across the IEX system, causing the finished water pH to be below the target pH of 8.5. The town had no ability to correct the pH downstream of the IEX system, and therefore was reluctant to reduce the IEX influent target pH to below 8.8. The resin was subsequently regenerated with a brine solution and the IEX system was put back in operation as Run 2.

Run 2 (Dec. 21-26, 2015)

During Run 2, the town used the same target pH in the IEX influent of 8.8 as during Run 1. The town tweaked the new temporary CO₂ dosing skid further during this run to create a more stable influent pH profile. Most of the filtered water was processed through IEX Vessel No. 1, with the remainder in Vessel No. 2 and No. 3. The graphics were very similar to Run 1. Run 2 was aborted abruptly after 455 BVs due to the presence of odor in a single effluent sample of Vessel No. 1. Further observations were very similar to those of Run 1.

The resin was subsequently regenerated with a brine solution and put back in operation as Run

3. Further discussions were held regarding pH values and corrosion control and it was decided to reduce the influent IEX target pH slightly.

Run 3 (Dec. 29, 2015-Feb. 26, 2016)

During Run 3, the town changed the target pH in the IEX influent to 8.4 to create a little buffer towards the limits of odor release at pH values of around 9. Also, the run was continued (in lieu of abortion as done with runs 1 and 2) when odor was detected after around 500 BVs. At that time, the pH profiles in the influent dropped, causing the odor to disappear instantly. The values of color and odor in the IEX effluent of Vessel No. 1 are depicted in the graphic on the left in Figure 7, whereas the pH profiles in the influent and effluent of Vessel No. 1 are depicted in the graphic on the right. This run was aborted after 5,000 BVs or 12 mil gal (MG) due to color breakthrough.

Further observations revealed that:

- ◆ The pH in the influent was still varying; in this case, around the pH set point of 8.4.
- ◆ Initially, the effluent pH was lower than in the influent; after 750 BVs, the pH in influent and effluent was the same, and this continued until the end of the run.
- ◆ At the end of the run when the loading rate of that vessel was significantly reduced, the pH drop increased again, suggesting that the contact time is a variable.
- ◆ The release of TMA is reversible; after odor was detected, the influent pH was reduced to 8.0-8.2, eliminating odor quickly.
- ◆ Spikes in influent color resulted in increases in effluent color.
- ◆ During the initial phase of the run, some alkalinity was lost between the influent and effluent that coincided with the pH drop, confirming the hypothesis presented.

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Figure 5. Softener Effluent pH, Hardness and Alkalinity (left), pH Before / After Recarbonation (right)

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- The graphs for Vessel No. 2 and No. 3 (not shown) were very similar to the graphs shown for Vessel No. 1, demonstrating that the phenomena are repeatable.
- The pressure drop across the IEX system remained low and was measured to be maximum 25 percent of the maximum allowable drop of 10 pounds per sq in. (psi), specified by the system integrator.

Conclusions

Foul odor released by the IEX system at the town's System 3 WTP was caused by high pH values of the IEX influent. The foul odor was identified as TMA. First, bench tests, and then full-scale tests during the IEX system recommissioning, confirmed the pathway hypothesis of the high IEX influent pH conditions, initiating the Hoffman's reaction and causing TMA to release from the resin into the water. The Hoffman's reaction, and therefore the TMA release, can be eliminated by reduc-

ing the IEX influent pH to around 8.4 with CO₂, also benefiting alkalinity levels in finished water. Another observation was a pH drop in the initial phases of a run, caused by the absorption of bicarbonate to the resin, leaving Ca²⁺ unassociated. The TOC and color breakthrough in Run 3 were observed after 12 MG treated, or 5,000 BVs, which is considered to be an improvement to prior conditions, potentially saving salt usage.

The town identified measures to enable stable pH conditions of around 8.5 in the finished water for corrosion control under different conditions. The short-term measure is to stagger the run times of IEX vessels to have a finished-water blend to dampen pH and alkalinity swings. The long-term measure, implementation of a sodium hydroxide system downstream of the IEX system to add alkalinity to the treated water, was put in operation in mid-2016. The permanent CO₂ system is anticipated to be operation by 2017.

Since recommissioning of the IEX system, foul odor has been eliminated from the fin-

ished water, color levels are low, and recommended pH values for corrosion control have been maintained.

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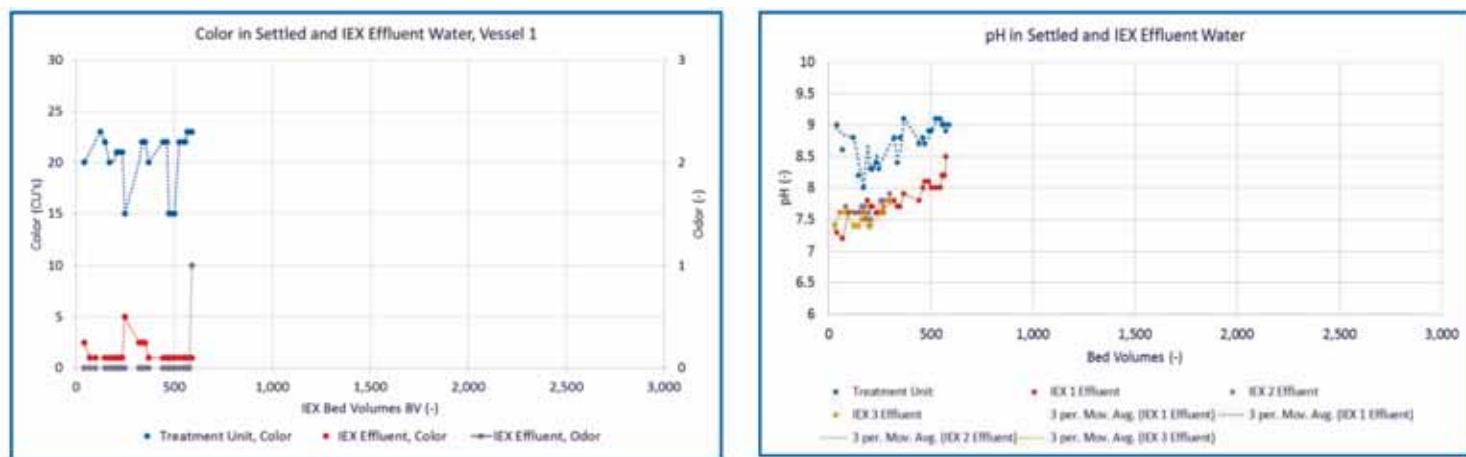


Figure 6. Color, Odor (left), and pH of IEX Influent, Effluent (right) as a Function of Run Time (Run 1)

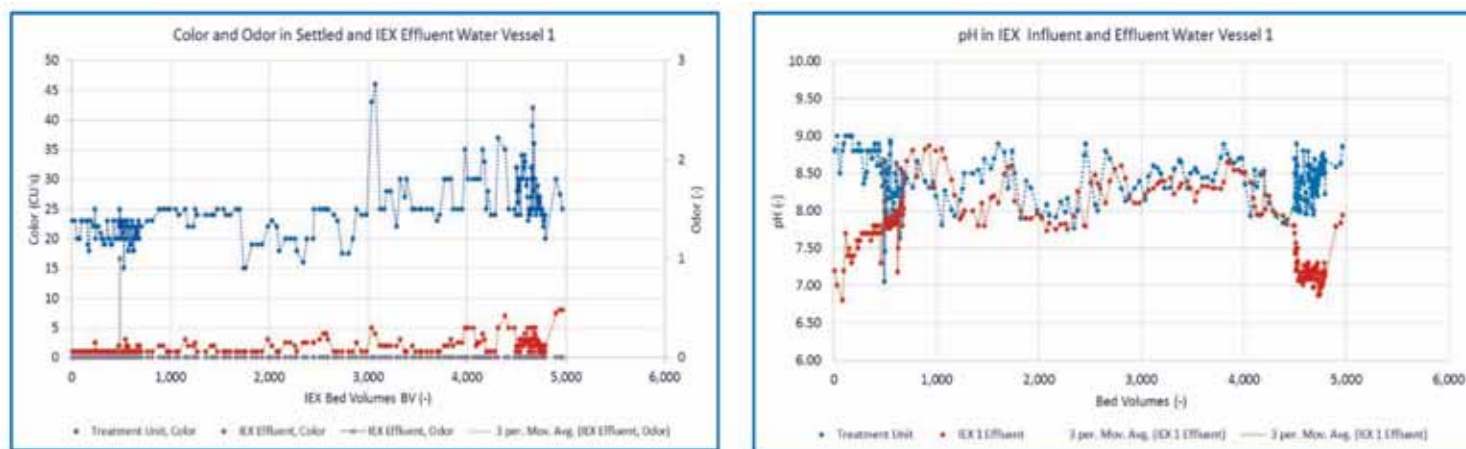


Figure 7. Color, Odor (left) and pH of IEX Influent, Effluent (right) as a Function of Run Time (Run 3)

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