USE OF A MAGNETIC ION EXCHANGE RESIN FOR REDUCED COAGULANT DEMAND AND THE REMOVAL OF DISSOLVED ORGANIC CARBON (DOC) TO MEET EPA DBP STANDARDS IN SOUTH CAROLINA

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Tightening EPA standards for disinfection by-products (DBPs) will make it necessary for many utilities in South Carolina to remove a large fraction of dissolved organic carbon (DOC) from their water supplies prior to disinfection. For many water sources, this means higher volumes of chemicals necessary for enhanced coagulation. This raises chemical costs as well as sludge treatment costs for a process that may only achieve borderline DBP compliance.

The MIEX® Resin specifically targets the removal of DOC compounds such as humic and fulvic acids from drinking water supplies. These negatively charged ions are removed from water by exchanging with a chloride ion on active sites at the resin surface. This resin has demonstrated the ability to remove the low molecular weight fraction of DOC that cannot be removed by coagulation, allowing lower treated water DOC levels to be achieved.

Unlike conventional packed bed ion exchange processes, the very small size of this magnetized resin allows the removal of anions to occur in a stirred contactor, much like a flash mixer in a conventional water treatment plant. Under mixing conditions, the resin beads are uniformly dispersed in water to maximize the kinetics of ion exchange and minimize the media inventory. A magnetic component is built into the resin particle structure to allow the beads to rapidly agglomerate into fast settling particles when mixing is ceased. This rapid settling enables conventional up-flow settlers to be used for resin-water separation. While the treated water overflows from the settler, the resin is recovered as a concentrated underflow stream. The efficiency of resin recovery exceeds 99.9% at very high settler rise rates (6gpm/ft^2).

This paper will discuss the performance of jar testing MIEX® Ion-Exchange Resin to remove DOC from various water sources in South Carolina, the applicability of the technology for achieving the EPA Stage 1 and upcoming Stage 2 DBP Rules, and its effect on coagulant demand during downstream treatment. The results of recent jar testing at the North Augusta, Camden, Grand Strand, Santee Cooper, Orangeburg, Bennetsville, and Georgetown Water Treatment Plants demonstrate the potential for DOC reduction of the MIEX® Process on different water sources. A pilot study completed in Louisburg, NC will also be detailed to exhibit more complete testing of the MIEX® Process, where DOC reductions were achieved on a continuous process with subsequent reductions in treated water DBPs.

INTRODUCTION

In South Carolina there are many drinking water supplies where DOC removal and DBP compliance have become a concern. On-site jar testing was completed at six South Carolina water treatment plants in August 2004: North Augusta, Camden, Grand Strand, Santee Cooper, Georgetown, and Orangeburg. Georgetown Raw Water was also sent to the WesTech Engineering Laboratory in November 2004 for comprehensive jar testing. The Louisburg project, completed in September 2003, has been included to demonstrate the DOC removal on a pilot scale. For this trial, the pilot unit ran continuously and sampling commenced once operating conditions reached steady state. The objectives of the testing were to reduce TOC levels, thereby lowering the potential to form DBPs in the finished water and allowing for reductions in downstream chemical demand.

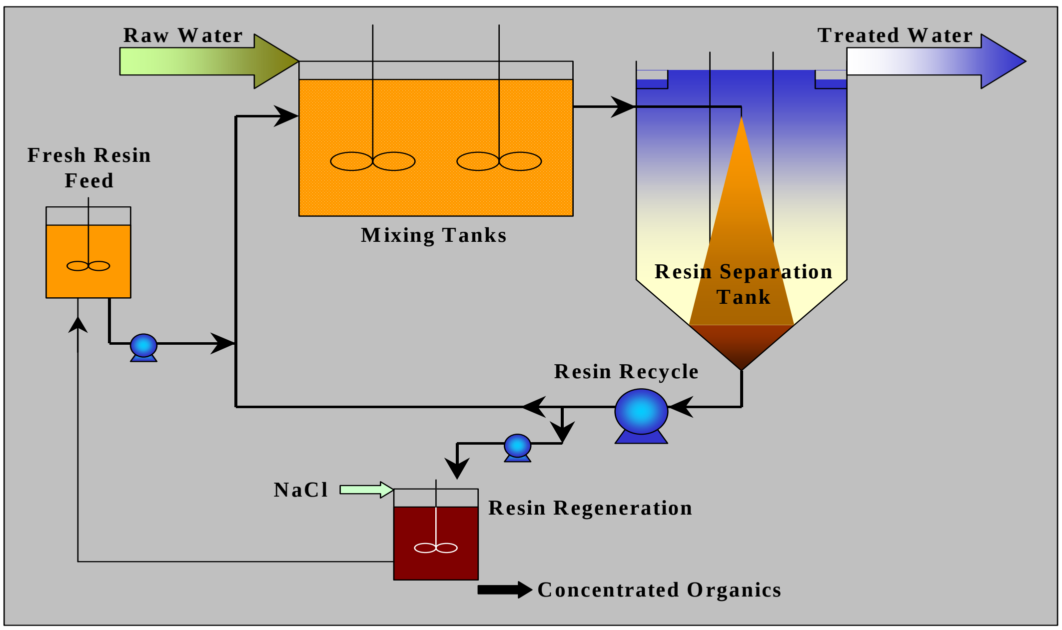

Figure 1: MIEX® Process Flow Diagram

METHODOLOGY

<u>MIEX® Resin On-Site Jar Tests</u>

MIEX® resin jar tests were performed by adding 15 mL/L of MIEX® resin to a 2-liter raw water sample and agitating at 140 rpm in a jar testing apparatus. One 2-liter jar with raw water was mixed for a control. Samples were withdrawn from the jars after 20 minutes. The samples were run through a 0.45-micron pore size filter then measured for either true color, ultraviolet absorbance at a wavelength of 254 nm (UV_{254}), or DOC, depending on the laboratory equipment available at each site. True color and UV_{254} absorbance were typically measured using a HACH DR4000U Spectrophotometer. One liter of the raw water control and one liter of MIEX® Resin treated water were then each placed in a clean 2-liter jar for coagulation testing.

MIEX® Resin Pre-treatment Followed by Coagulation (On-site)

The raw water sample was dosed with the determined coagulant dose, simulating current plant treatment conditions as a control. The MIEX® pre-treated water was dosed with roughly one third of the current plant coagulant regimen. This method was chosen to better demonstrate the effect of MIEX® pre-treatment on downstream coagulant demand. A standard jar test procedure was typically used. At some locations, the jar testing procedure normally used at that particular plant was followed instead of the standard procedure, all of which included rapid mix, flocculation mix, and settling stages. After the jar test was performed, samples were then passed through a 0.45 μm filter and analyzed.

WesTech Engineering Off-Site Comprehensive MIEX® Resin Jar Testing

The Cities of Bennetsville and Georgetown each sent 10 gallons of raw water to the WesTech Engineering Laboratory for a full range of MIEX® Resin tests. The first test was conducted using MIEX® Resin over a range of resin concentrations on the raw water sample. The second jar test was a coagulant control test. The jar test procedure currently being used at the Georgetown treatment facility was used in the coagulant control testing. These procedures were designed to simulate the organic removal observed at the plant. The final test was a combined treatment jar test. The water was first treated using the resin dose and mix time selected from Test #1. The MIEX® Resin treated water was then treated with selected aluminum sulfate and ferric chloride dosages to determine the lowest dosage that produced the greatest turbidity, UV_{254}, and color reduction.

Pilot Plant Operation

The MIEX® Process pilot plant was configured as shown in Fig. 1. Raw water was introduced to the Mixing Tanks at a measured flow rate. Since the volume of the Mixing Tanks was known, a theoretical contact time was established. The Mixing Tanks contained a specified amount of MIEX® Resin previously determined in bench scale tests to be effective for the given water source. Mechanical mixers were used to suspend the MIEX® Resin, and assure good contact between the resin and the raw water.

The slurry from the Mixing Tanks was distributed to the Resin Separation Tank where the MIEX® Resin quickly agglomerated and settled to the bottom of the vessel. The treated water flowed to a collection launder at the top of this tank, and was then available for testing. Using an underflow pump, the settled MIEX® Resin was reintroduced to the Mixing Tanks at a rate that maintained the MIEX® Resin concentration.

A small percentage of the underflow from the Resin Separation Tank was withdrawn and placed in the Resin Regeneration Tank. An equivalent amount of fresh MIEX® Resin was added to the recirculation line to maintain the concentration of MIEX® Resin in the Mixing Tanks. This percentage of withdrawn spent resin and reintroduced fresh resin is known as the regeneration rate. For example, if 5% of the underflow was sent to the regeneration tank and 95% of the underflow was recycled to the front of the process, the system was running with a 5% regeneration rate. Once there was a sufficient volume of MIEX® Resin in the regeneration tank, the resin was regenerated using a 12% brine solution (120g/L NaCl). When the resin batch was regenerated, it was transferred to the Fresh Resin Feed tank to be reintroduced to the Mixing Tanks. A certain amount of brine containing concentrated organics is wasted periodically.

Pilot Plant Sampling and Analyses

Once the system was operating under steady-state conditions, testing of the treated water commenced. Samples were collected from the following sources: Raw Water, MIEX® Resin treated water, Raw Water treated with the existing plant treatment regimen, MIEX® Resin treated water followed by treatment with the selected, reduced coagulant dose. The samples were analyzed for the following contaminants using the 20^{th} Edition of *Standard Methods for Examination of Water and Wastewater* as a guide for all testing: TOC, DOC, true color, ultraviolet absorbance at a wavelength of 254 nm (UV_{254}), DBPs.

The coagulant demand of water treated by the MIEX® Process was determined by measuring UVA on jar test samples with various levels of coagulant, and then selecting jar that the provided the largest benefit to water quality at the minimum dose (i.e., point of diminishing returns).

RESULTS

North Augusta, SC

These results show that MIEX® resin alone achieved a 75% reduction in UV_{254} Absorbance after 20 minutes of contact time, lowering the raw water UV_{254} from 0.032 to 0.008. The plant control of 30 mg/L aluminum sulfate achieved a 28% reduction down to 0.023, and MIEX® resin followed by coagulation with 10 mg/L aluminum sulfate showed an 84% reduction down to 0.005.

The true color was reduced to 0 Pt-Co by MIEX® Treatment and by the coagulant control. The DOC was measured in the raw water and in the water treated with MIEX® resin followed by a reduced coagulant dose, the latter decreasing the DOC from 1.7 mg/L to 0.824 mg/L.

Camden, SC

In Camden raw water MIEX® resin alone achieved an 83% reduction in UV_{254} Absorbance after 20 minutes of contact time, lowering the raw water UV_{254} from 0.127 to 0.022. The plant control of 30 mg/L aluminum sulfate achieved a 59% reduction down to 0.052, and MIEX® resin followed by coagulation with 10 mg/L aluminum sulfate showed a 90% reduction to 0.013.

MIEX® Treatment followed by a reduced coagulant dose lowered the true color 95%, while the plant control reduced the true color 89%.

Grand Strand, SC

Here MIEX® resin alone achieved an 80% reduction in UV_{254} Absorbance after 20 minutes of contact time, lowering the raw water UV_{254} from 0.799 to 0.099. The plant control of 140 mg/L aluminum sulfate achieved an 86% reduction to 0.088, and MIEX® resin followed by coagulation with 30 mg/L aluminum sulfate showed a 96% reduction to 0.017.

Table 2 shows the DOC and color removal

Table 2: DOC Removal

	DOC (mg/L)
Raw Water	14
MIEX® resin alone	3.4
Plant Control	4.9
MIEX® resin + coagulant	1.9

Santee Cooper, SC

These results show that MIEX® resin alone achieved an 87% reduction in UV_{254} Absorbance after 20 minutes of contact time, lowering the UV_{254} to 0.027. The plant control of 21 mg/L aluminum sulfate and 0.5 mg/L polymer achieved a 60% reduction to 0.083, and MIEX® resin followed by coagulation with 5 mg/L aluminum sulfate showed an 88% reduction to 0.025.

Orangeburg, SC

In North Edisto River water MIEX® resin alone achieved a 70% reduction in UV_{254} Absorbance after 20 minutes of contact time, lowering the raw water UV_{254} from 1.182 to 0.347. The plant control of 75 mg/L aluminum sulfate achieved an 82% reduction to 0.208, and MIEX® resin followed by coagulation with 30 mg/L aluminum sulfate showed a 99% reduction to 0.010. The true color was reduced to 1 Pt-Co by combined MIEX® Treatment, while the plant control reduced the true color to 3 Pt-Co. The raw water true color was 109 Pt-Co.

Bennetsville, SC

A MIEX® fresh resin dose of 20 mL/L and 10-minute batch mix time was selected. These operating conditions in full-scale application should reduce the UV_{254} to 0.079, compared to 0.437 in the raw water - an 82% reduction. Additional mixing time did not significantly lower the UV_{254}.

Testing aluminum sulfate demonstrated that using the alum as a coagulant, at the plant dosage of 80 mg/L, would reduce the UV_{254} from 0.437 to 0.085, a reduction of 80%. Bennetsville applies NaOH for pH adjustment.

The MIEX® Resin pre-treated water was coagulated, with alum, at six dosages to determine the minimum amount necessary after MIEX® Resin pre-treatment to achieve the lowest Turbidity, UV_{254}, and True Color values. The alum dose selected was 5 mg/L, which achieved a reduced UV_{254} to an undetectable level and required no application of NaOH. The combined treatment reduced the true color to 0 Pt-Co.

Samples of the raw water, plant control, MIEX® Resin treated, and the MIEX® /Coag were sent to the Georgetown WTP laboratory for DOC analysis. Current plant treatment reduced the DOC by 51%, while combined MIEX® Resin treatment reduced the DOC by 80% using 88% less coagulant.

Georgetown, SC

A MIEX® fresh resin dose of 2 mL/L and 90-minute batch mix time was selected. This corresponds to a contactor concentration of 20 mL/L with a contact time of 27 minutes with a 10% regeneration rate in full-scale operation. These operating conditions should reduce the UV_{254} to 0.163, compared to 0.413 in the raw water - a 61% reduction. Additional mixing time did not significantly lower the UV_{254}.

Testing aluminum sulfate demonstrated that using the alum as a coagulant, at the plant dosage of 80 mg/L, would reduce the UV_{254} from 0.413 to 0.091, a reduction of 78%. Ferric chloride at a dosage of 80 mg/L reduced the UV_{254} from 0.413 to 0.077. Georgetown also requires the application of NaOH for pH adjustment.

The MIEX® Resin pre-treated water was coagulated, with alum, at six dosages to determine the minimum amount necessary after MIEX® Resin pre-treatment to achieve the lowest Turbidity, UV_{254}, and True Color values. The same was completed with ferric chloride. The alum dose selected was 10mg/L, which achieved a reduced UV_{254} of 0.014 and required no application of NaOH. The ferric dose selected was 10mg/L, which achieved a reduced UV_{254} of 0.015 and required no application of NaOH. Both coagulants reduced the true color to 0 Pt-Co.

Samples of the raw water, plant control, MIEX® Resin treated, and the MIEX® /Coag were sent to the Georgetown WTP laboratory for DOC analysis. Current plant treatment reduced the DOC by 57%, while combined MIEX® Resin treatment reduced the DOC by 83% using 94% less coagulant.

Louisburg, NC

A trial of the MIEX® Process was conducted at the Louisburg Water Treatment Plant, where the results indicated an average DOC reduction from 13.1 mg/l in the raw water to 4.5 mg/l in water pre-treated by MIEX® Resin followed by coagulation. This compares to DOC levels in the finished water from the current treatment plant of approximately 6.1 mg/l. By removing DOC from raw water, the coagulant demand was reduced on average from 101 mg/l to 41 mg/l PACl.

The Louisburg water plant had already established a correlation between DOC and DBPs. Due to the availability of this correlation and the resources required for DBP testing, the simpler surrogate tests of UVA and DOC were primarily used to judge the performance of the system. Additionally, Trihalomethane Formation Potential (THMFP) and Haloacetic Acid Formation Potential (HAAFP) analyses were performed in accordance with EPA methods 524.2 and 552.2. These results from the THMFP and HAAFP analyses showed that water pre-treated with MIEX® Resin can lower TTHM and HAA5 levels in treated water by approximately 60% and 70% over current treatment practices, respectively.

DISCUSSION

The primary goal of the pilot plant study was to demonstrate that the MIEX® Process could achieve 50% or greater removal of organic carbon DBP pre-cursors. The results show that pre-treating water by the MIEX® Process provided a large margin of safety in meeting EPA standards. Although the average UV_{254}\organics removal by coagulation alone was 66%, this provides only a small safety margin for meeting the standards. The average removal using MIEX® Pre-Treatment was 91%. Table 3 shows the average organics removal for each location with and without MIEX® Resin Pretreatment.

Table 3: UVA Reduction

Location	**Reduction With MIEX® Resin Pre-Treatment**	**Reduction With Current Treatment Regimen**
North Augusta, SC	84%	24%
Camden, SC	90%	59%
Grand Strand, SC	96%	86%
Orangeburg, SC	99%	82%
Santee Cooper, SC	88%	60%
Bennetsville, SC	>99%	80%
Georgetown, SC	96%	81%
Louisburg, NC*	73%	54%

*Louisburg percentages based on DOC Removal instead of UV_{254}.

The data also suggests that MIEX® Process pre-treatment can reduce coagulant demand by more than 50%. Table 4 shows the coagulant dosage used with and without MIEX® Resin pre-treatment which should be associated with the reductions above in Table 3.

Table 4: Coagulant Dosage			
Location	**Dosage With Current Treatment Regimen**	**Dosage With MIEX® Resin Pre-Treatment**	**Percent Reduction**
North Augusta, SC	30 mg/L alum	10 mg/L alum	67%
Camden, SC	30 mg/L alum	10 mg/L alum	67%
Grand Strand, SC	140 mg/L alum	30 mg/L alum	79%
Orangeburg, SC	75 mg/L alum	30 mg/L alum	60%
Santee Cooper, SC	21 mg/L alum	5 mg/L alum	76%
Bennetsville, SC	80 mg/L alum	5 mg/L alum	94%
Georgetown, SC	80 mg/L ferric	10 mg/L ferric	88%
Louisburg, NC*	101 mg/L PACl	41 mg/L PACl	59%

It should also be noted that pH correction employed by many facilities such as Georgetown, SC was not needed with the reduced coagulant dose.

CONCLUSIONS

These documented results show that MIEX® Treatment combined with conventional coagulation was successful in reducing UV_{254} by 73% to >99%. The coagulant demand was reduced by 59% to 88%. All of the results indicate that MIEX® Treatment is a viable option for improving TOC removal and therefore lowering DBP levels, while reducing overall chemical usage.

ACKNOWLEDGEMENTS

We wish to thank North Augusta, Camden, Grand Strand, Orangeburg, Santee Cooper, Bennetsville, and Georgetown in South Carolina, and the City of Louisburg, North Carolina for their assistance in coordinating and executing these projects. We also wish to thank the staff of WesTech Engineering, Orica Watercare, and Interstate Utilities for providing the test equipment and resources necessary to complete this work.