USE OF A MAGNETIC ION EXCHANGE RESIN TO IMPROVE DBP PRECURSOR REMOVAL AND REDUCE COAGULANT USAGE AT LEE COUNTY'S OLGA WTP.

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Introduction

The 5 MGD Olga WTP in Lee County, Ft Myers, treats water from the Caloosahatchee River where TOC and color levels range from 15-25mg/L and 80-350 Pt Co Units respectively. This surface water presents many treatment challenges and treatment costs are high with alum doses in excess of 200mg/L required during times of the year to provide an adequate treated water quality.

As part of Lee County's treatment plant reservoir and plant improvements for the Olga Water Treatment Plant (WTP), Parsons has been contracted to replace the current alum coagulation feed system with a ferric sulfate coagulation feed system. In order to determine chemical feed rates and their impact on water quality, disinfection and the formation of disinfection by-products, three days of on-site jar testing were conducted at the Olga WTP. MIEX® ion exchange resin was also evaluated for enhanced removal of dissolved organic carbon (DOC). DOC serves as the precursor matter in the formation of disinfection by-products with the addition of chlorine. Aluminum sulfate (alum), powder activated carbon (PAC) and polymer in conjunction with ferric sulfate were also tested. Following the jar tests a 6-week trial was conducted to further investigate MIEX® treatment followed by coagulation with ferric sulfate.

To determine the impacts these treatment regimes have on disinfection, both chlorine dioxide and chlorine decay tests were performed on optimum treated waters from the jar testing and pilot plant trial. For waters treated with ferric sulfate and MIEX® followed by ferric sulfate, disinfection by-product formation potentials were conducted using chlorine to estimate the concentrations of trihalomethanes and haloacetic acids that would be formed if chlorine were used for primary disinfection.

This paper will discuss the results of the bench testing and MIEX® pilot plant trial conducted at Lee County's Olga WTP and compare water quality data and operating costs of the treatment alternatives investigated by Parsons.

Experimental Procedure

Jar Testing

Bench scale jar tests were carried out at the Olga WTP laboratory from May 7-8, 2002. The objective of this series of jar tests was to determine the effectiveness of MIEX® resin followed by both alum and ferric sulfate coagulation in removing TOC from the raw water and compare the performance with alum and ferric sulfate coagulation only. Raw water samples were taken using a submersible pump located in the river at the plant intake point.

The jar testing procedures for MIEX® resin and alum/ferric sulfate jar tests were as follows:

MIEX® Resin Tests

These tests were performed by adding resin doses to 2-liter raw water samples and agitating the samples at 130 rpm on a jar testing apparatus to keep the resin in suspension. After 2.5 to 10 minutes of agitation the resin was allowed to settle and samples were passed through a 0.45 micron filter for on-site color and

UV_{254} Absorbance analyses and off-site DOC analyses. Alkalinity, pH and turbidity were measured on unfiltered samples. The optimum MIEX® resin dose was chosen based on color and UV_{254} results.
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MIEX® Pretreatment Followed by Alum and Ferric Sulfate Coagulation

A control alum jar test was performed where the dose used currently at the plant was bracketed by higher and lower alum doses to select the optimum dose based on color and UV_{254} removal. A similar test was performed to select the optimum ferric sulfate dose.

12-liters of raw water was then treated in 6 jars at the optimum MIEX® dose, and after 2.5-10 minutes of agitation the resin was allowed to settle for 5 minutes. The treated water from each jar was then decanted into a container and from this, five 2-liter samples were poured into jars for alum and ferric sulfate jar testing.

After MIEX® resin pretreatment, lower coagulant doses were chosen compared to those used in the control tests to compensate for the TOC already removed by the MIEX® resin. A control was also prepared, where 2 liters of raw water was dosed with the optimum alum or ferric sulfate dose determined previously.

The procedure for the coagulation jar tests was as follows:
- Rapid mix: 60 rpm for 1 minute
- Flocculation: 35 rpm for 7 minutes
- Settling: 0 rpm for 5 minutes

Samples were allowed to settle for 5 minutes prior to measurement of turbidity. Settled water samples were then passed through a 0.45 micron filter for UV_{254} Abs, color and DOC analyses. Alkalinity and pH were also measured on unfiltered samples.

Pilot Plant Trials

The trial objectives were as follows:
- To verify bench scale tests performed by Orica Watercare, WesTech and Parsons could be reproduced on a continuously operating pilot plant.
- To obtain adequate results to obtain FDEP approval for a full-scale installation.
- To demonstrate that MIEX® treatment followed by coagulation can consistently achieve the following performance objectives:

Table 1: **Treated Water Performance Objectives**

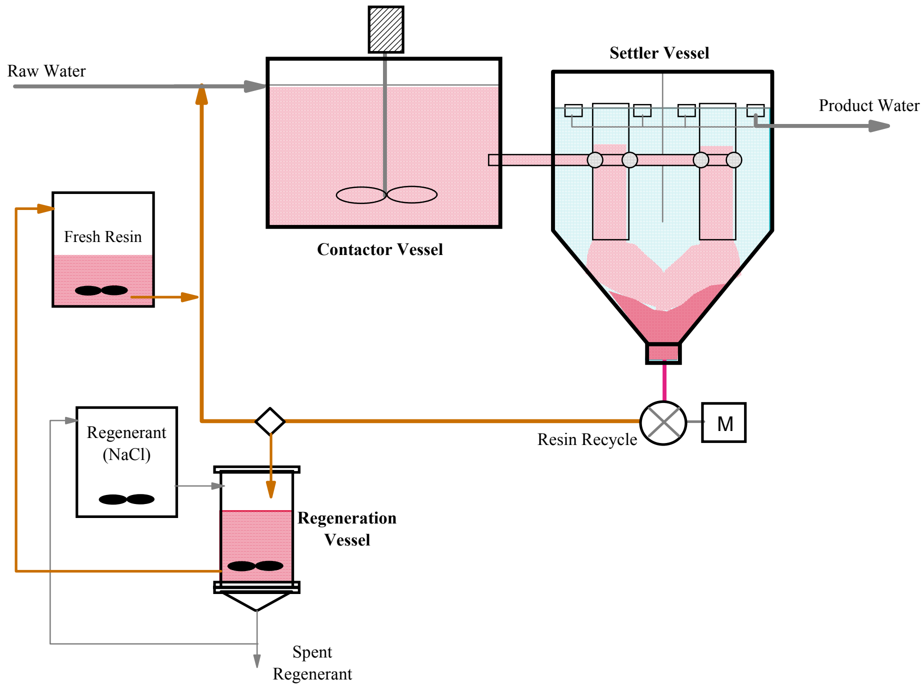
Parameter	Target
Color	< 6 pt/Co
Chlorine Dioxide Residual	> 0.4 mg/L after 10 minutes with an initial dose of 1.2 mg/L*
Chlorine Residual	> 2.0 mg/L after 10 minutes with an initial dose of 4.0 mg/L**
Ferric Sulfate Dose	Minimize use to not less than 20 mg/L

*Required residual and time to achieve 0.5 log removal for Giardia and 2-log removal for viruses using chlorine dioxide given a pH between 6.0 to 9.0 and a temperature greater than 10 ºC.

**Required residual and time to achieve 0.5 log removal for Giardia and 2-log removal for viruses using chlorine given a pH between 8.0 and a temperature greater than 20 ºC.

Two 3 week trials were conducted using MIEX® pilot plants with two different configurations. The first trial was conducted using a ‘conventional’ mixed bed/settler configuration (Figure 1) while a fluidized bed was tested on the second trial. The performance of both systems was similar and this paper will focus on the trial results of the conventional configuration which has been recommended for the full scale installation.

Figure 1: **MIEX® Mixed bed/Settler Configuration**



The trial was conducted using a 2-gpm MIEX® pilot plant shown in Figure 2. Raw water was pumped from the Olga WTP’s raw water intake in the Caloosahatchee River using a submersible pump.

Results

Bench Scale Results

The raw water characteristics during the jar testing period are shown in Table 2. The bench scale results showed that MIEX® treatment followed by ferric sulfate coagulation produced a treated water with significantly lower DOC levels than enhanced coagulation with either alum or ferric sulfate (Figure 7). Water treated by MIEX® followed by ferric sulfate also had significantly lower chlorine and chlorine dioxide demands which would give the Olga WTP greater flexibility in meeting disinfection requirements (Figures 3 and 4). The lower chlorine dioxide demand after MIEX® followed by ferric sulfate allowed chlorite levels to be maintained well below the EPA limit of 0.8mg/L whereas this limit was exceeded using ferric sulfate alone (Figures 5 and 6). The higher water quality was achieved at around 20% of the current WTP coagulant dose, which would significantly reduce costs for coagulant, pH correction chemicals and sludge disposal.

Table 2: **Raw Water Characteristics**

Date	5/7-8
Color – Pt/Co	92
True Color* – Pt/Co	48-49
UV - %T	26-27
UV Abs (254 nm) – cm^{-1}	0.569-0.585
TOC/DOC – mg/L	19/19-20
Turbidity – NTU	2.14-2.45
pH	8.07-8.24
Alkalinity – mg/L as CaCO3	152
Temperature – deg F	87

*Filtered through 0.45 micron filter.

Figure 2: **MIEX® Pilot Plant at Olga WTP**

Figure 3: **Chlorine dioxide demand and chlorite production for water treated with 150 mg/L of ferric sulfate.**

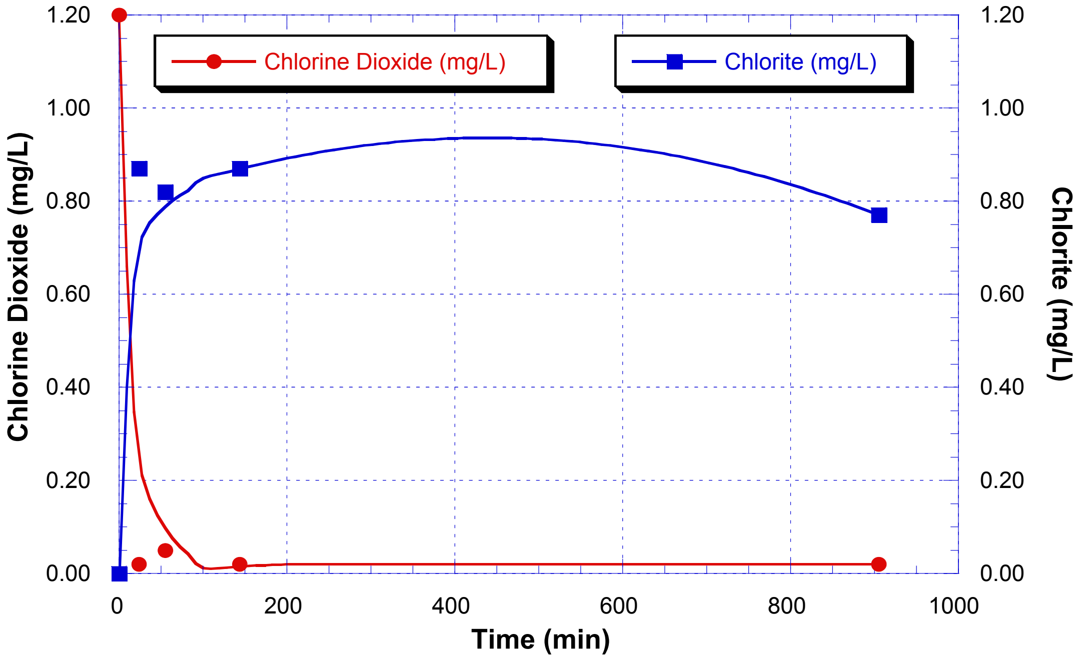


Figure 4: **Chlorine dioxide demand and chlorite production for water treated with 16 mL/L MIEX® for a contact time of 5 minutes followed by 30 mg/L ferric sulfate.**

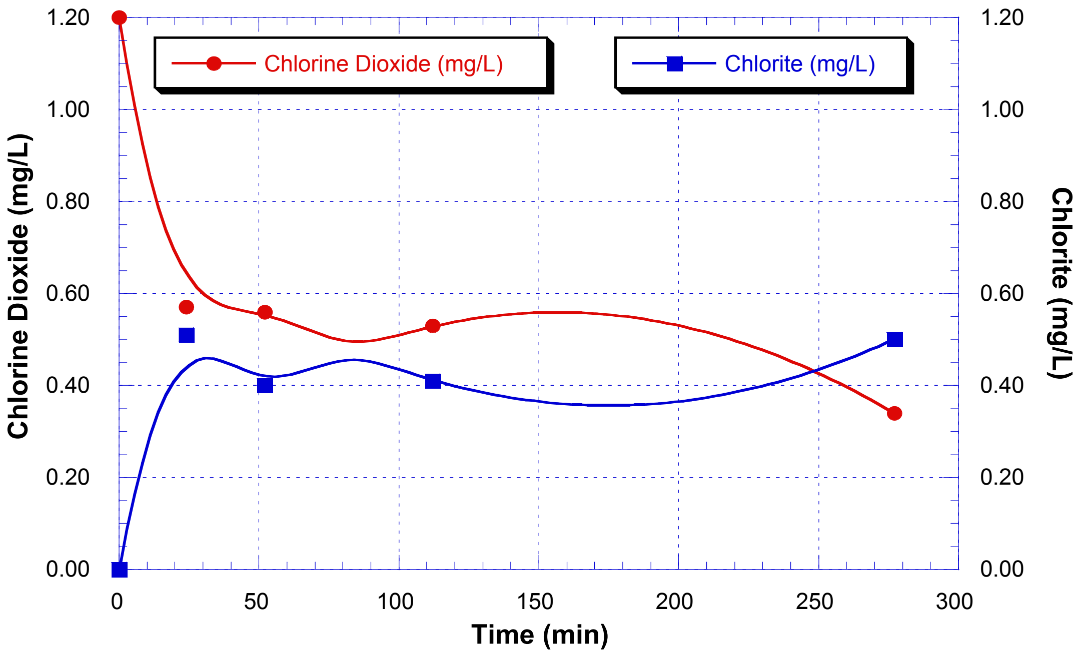


Figure 5: **Chlorine demand for water treated with 150 mg/L ferric sulfate**.

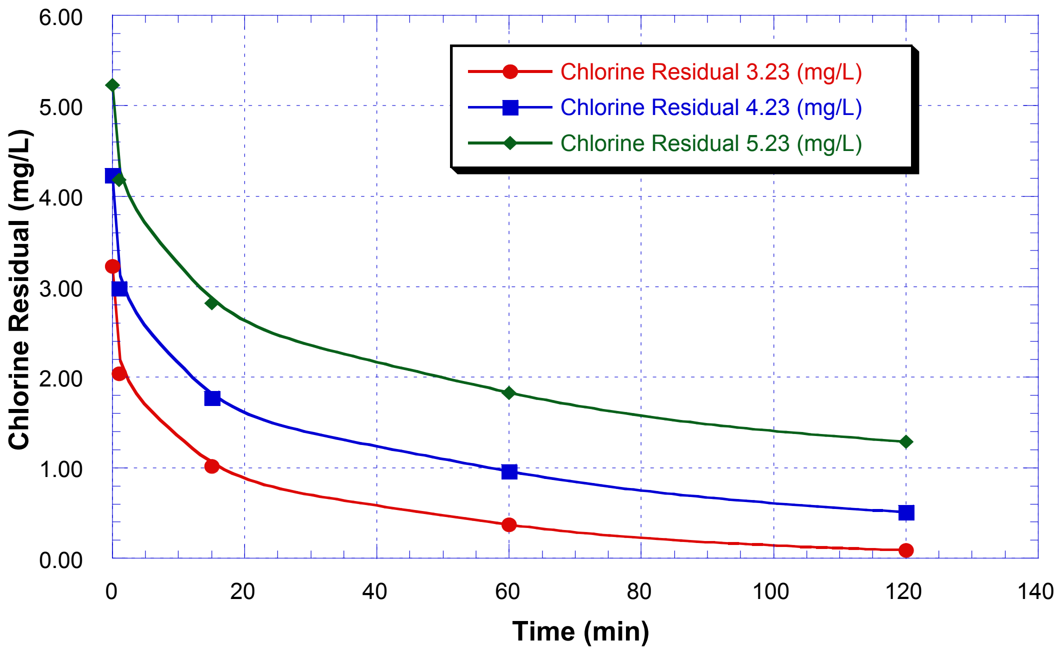


Figure 6: **Chlorine demand for water treated with 16 mL/L MIEX® for 5 minutes and then 30 mg/L ferric sulfate.**

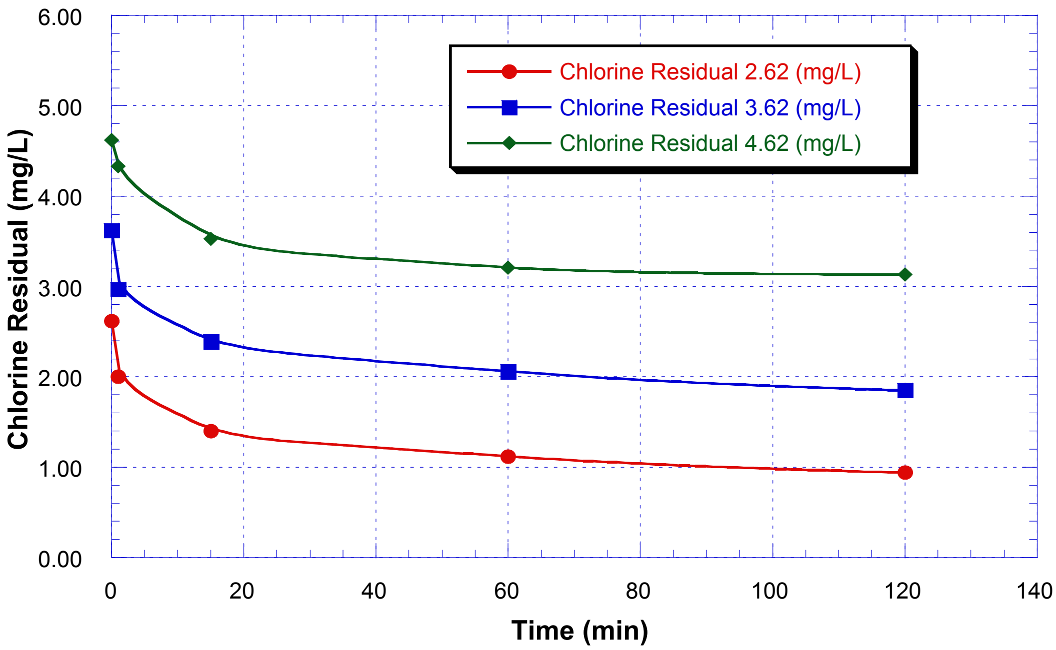
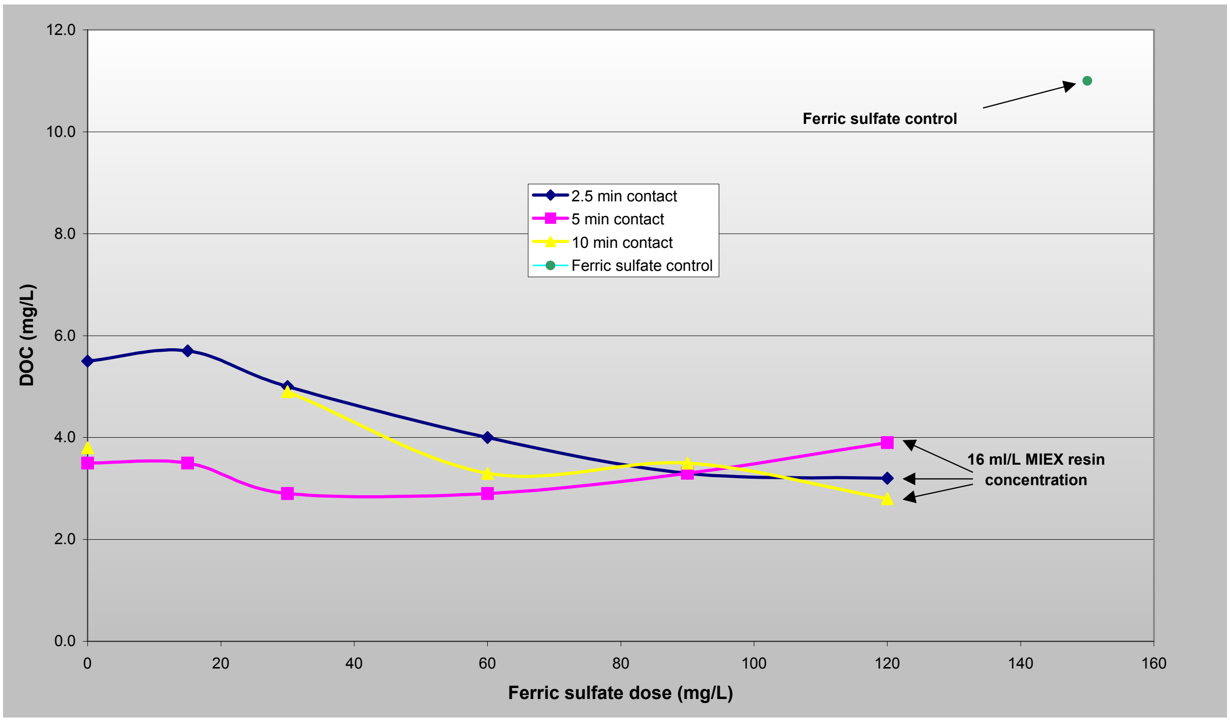


Figure 7: **Jar Test DOC Removal Results**



<u>Trial Results</u>

Following the bench scale tests a 6 week MIEX® pilot plant trial commenced on June 24, 2002. At the start of the trial, high rainfall increased the raw water color from 100 to over 300 Pt Co Units. The raw water characteristics during the trial period of June 24-July 16 are shown in Table 3.

Table 3: **Raw Water Characteristics during Trial**

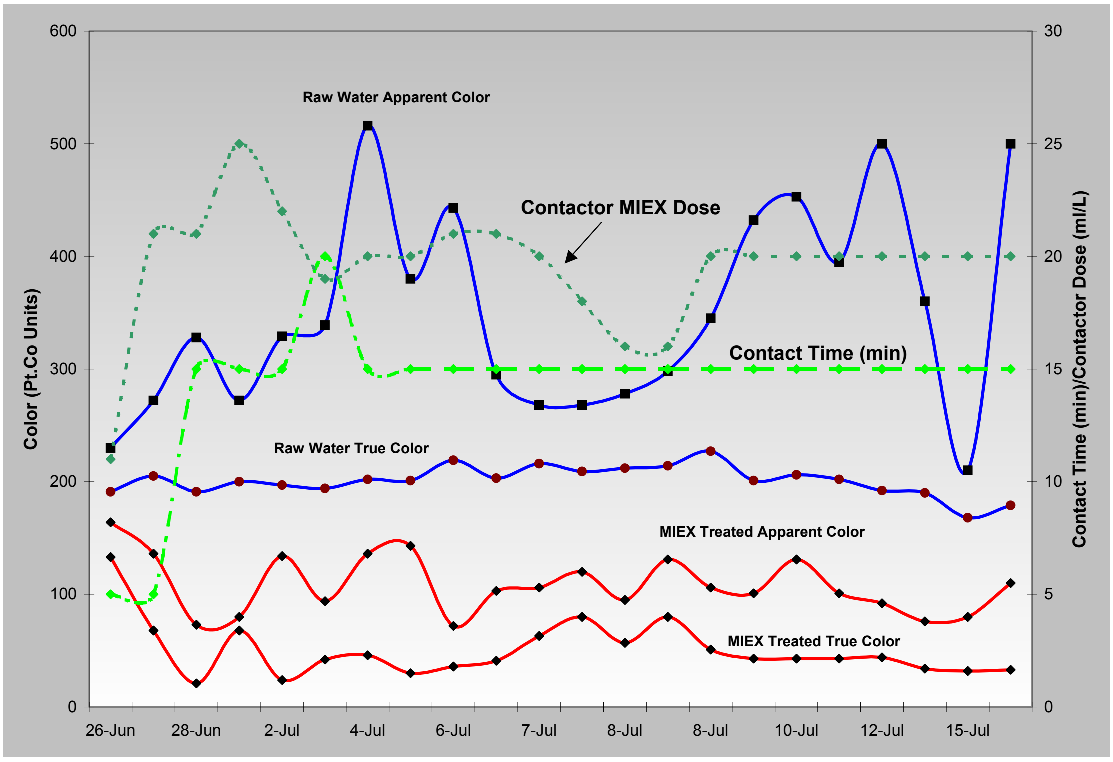
Parameter	**Analysis** (range)
pH	7.1-7.6
Alkalinity, mg/L	176-200
Total Hardness, mg/L $CaCO_3$	146-162
Apparent Color, Pt Co Units	268-516
True Color, Pt Co Units	168-227
Dissolved Iron. mg/L	0.15-0.20
Dissolved Manganese, mg/L	0.02
Sulfate, mg/L	12-30
Chloride, mg/L	40-76
UV Absorbance @ 254 nm	0.80-1.14
Total Organic Carbon, mg/L	19-21
Turbidity, NTU	1.9-21.8

The pilot plant was started up on June 25 with a resin concentration of 16ml/L and a contact time of 5 minutes which were determined to be the optimum from the jar tests conducted on May 7-8. Under these operating conditions the true color[1] of the pilot plant output was 133 Pt Co Units and when this was coagulated with 150 mg/L of ferric sulfate, the color was only reduced to 25 Pt Co Units. It was apparent that the raw water characteristics had changed significantly due to heavy rainfall since the jar tests where the true color had increased from around 48 to over 200 Pt Co Units (the plant alum dose at the time of the trial was 220 mg/L).

Contact time and resin concentration were then optimized to 15 minutes and 20 ml/L respectively. This reduced the true color to 20-40 Pt Co Units and a ferric sulfate dose of 60mg/L reduced the color to below the target of 6 Pt Co Units. These operating conditions were then kept constant (as much as possible) for the remainder of the trial.

Color removal results achieved by the pilot plant are shown in Figure 8. Other than during the initial optimization period and on July 7-8 when there was a problem with a regeneration sequence, the output from the pilot plant was fairly stable. It is interesting to note that while the raw water apparent (unfiltered) color fluctuated widely over the trial period, the true color only varied slightly.

Figure 8: **Color Removal Through Pilot Plant**



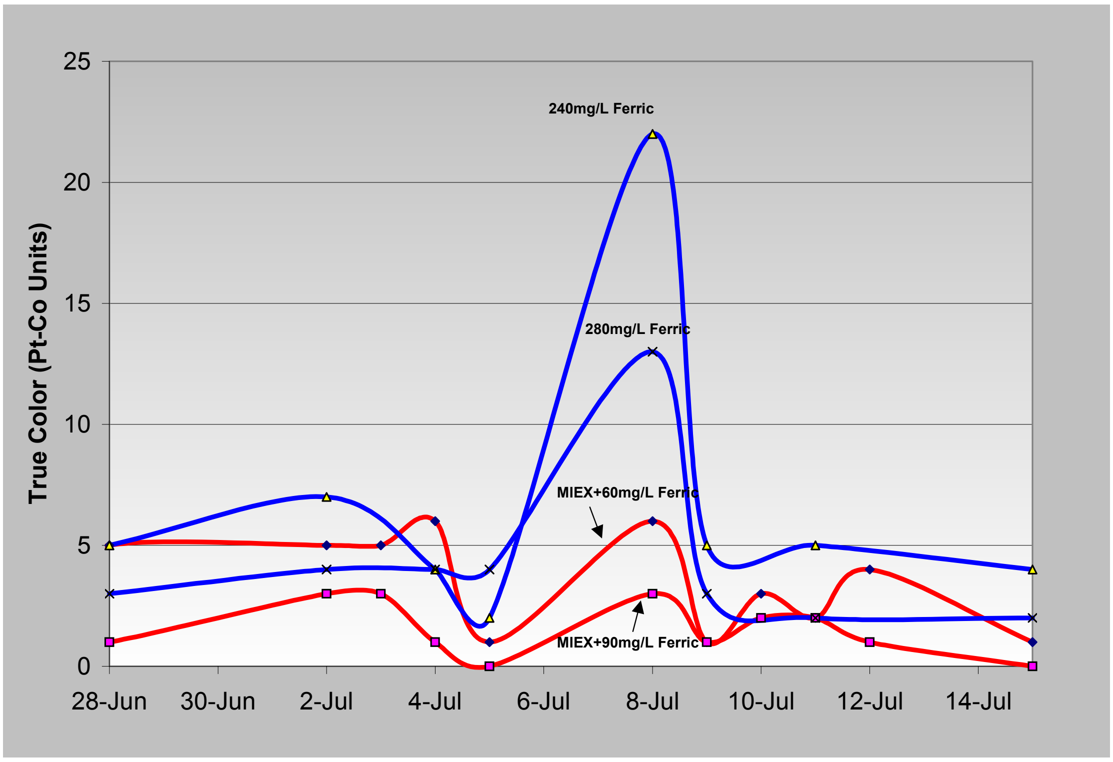
The results from jar tests conducted on the pilot plant output showed that the treated water color objective of less than 6 Pt Co Units was consistently achieved with a post MIEX® ferric sulfate dose of 60mg/L (Figure 9). The control ferric sulfate dose of 240mg/L achieved the treated water color objective on average if the result on July 8 is discarded. It is not known why the color on July 8 was so high as the raw

[1] Color after filtering through a 0.45micron filter.

water characteristics did not appear to be unusual. The MIEX®/ferric treated water color was also slightly higher on July 8 but this was probably due to the resin concentration falling to 16ml/L due to a mechanical problem on the pilot plant on this day. On average, MIEX® treatment followed by 60mg/L ferric sulfate produced a lower treated water color than the 240mg/L control ferric sulfate dose.

Note that after MIEX® followed by 60mg/L ferric sulfate the treated water pH was 6.70-7.13, which is above Lee County's minimum desired level on 6.5 (Figure 12). A ferric sulfate dose of 240mg/L in the control tests resulted in treated water pHs of 5.64-6.13 which is below the minimum desired level.

Figure 9: **Color Removal after Jar Tests**



The results of DOC analyses are shown in Table 4. Ignoring questionable results on July 4 and 11, The MIEX® pilot plant reduced raw water DOC levels from 19-21mg/L to 5.5-5.8mg/L. The optimum ferric sulfate control dose of 240mg/L provided an average treated water DOC level of 4.7mg/L at a pH of 6.0. MIEX® treatment followed by 60mg/L ferric sulfate provided an average treated water DOC level of 3.9mg/L at a pH of 6.9.

The results of THM and HAA formation potential analyses are shown in Table 5. While at the optimum MIEX®/ferric dose the DOC and UV_{254} levels were typically lower than the optimum ferric sulfate control dose, there was not much difference between the THM formation potentials of the two treatment regimes. There was a greater reduction in HAA formation potential after MIEX®/ferric treatment. All samples tested were well below the EPA Stage 1 THM and HAA standards of 80 and 60ppb respectively.

Table 4: **DOC Results**

MIEX Dose (ml/L)	Ferric dose (mg/L)	DOC (mg/L)					
		7/2/02	7/4/02	7/9/02	7/11/02	7/15/02	Ave
0	0	19	20	21	20	19	19.8
0	120	8.3	11	9.7	11	11	10.2
0	160	7.1	8.8	7.7	9.3	9.2	8.4
0	200	4.9	6.4	6.6	7.5	7.1	6.5
0	240	2.8	4.8	4.5	5.2	6.2	4.7
0	280	2	2.9	3.5	4.6	4.0	3.4
20	0		19*	5.8	10*	5.5	5.7
20	30		5.6	5.7	5.5	5.5	5.6
20	60	2.7	3.4	4.2	4.9	4.5	3.9
20	90		3.2	3.3	4.2	4.2	3.7
20	120		3	4.3	4.5	3.0	3.7
20	150		2.9	4.2	4.7	2.9	3.7

*Possible sample contamination or measuring error.

Table 5: **THM and HAA Formation Potential Results**

Date	MIEX Dose ml/L	Ferric dose mg/L	DOC mg/L	**UV_{254}**	**THMFP** ppb	**HAAFP ppb**
7/2/02	21	60	2.7	na	30	15
	0	200	4.9	na	36	34
7/9/02	20	60	4.5	0.053	50	16
	0	240	4.2	0.077	37	20
7/15/02	20	60	4.5	0.051	50	17
	0	240	6.2	0.118	56	46

na = not available

Chlorine and chlorine dioxide demand tests conducted during the trial are shown in Figures 10 and 11. These results show that the demands for these oxidants were lower after MIEX®/ferric sulfate treatment compared to ferric sulfate alone, although the difference was not as large as in the initial jar tests. The objective of maintaining a chlorine dioxide residual of 0.4 mg/L after 10 minutes was achieved after MIEX®/ferric sulfate treatment but not with ferric sulfate alone.

Figure 12 shows the final water pH after treatment with MIEX®/ferric sulfate treatment and ferric sulfate only. Jar tests on the MIEX® pilot plant output showed that the final treated water pH was above 6.5 for ferric sulfate doses up to 90mg/L. In the control tests, the minimum ferric sulfate dose (240mg/L) that would achieve the treated water color objective resulted in a final pH of around 6.0 This is below Lee County's preferred minimum pH of 6.5 to minimize corrosion of the treatment plant. To achieve a final pH of 6.5 or higher, a ferric chloride dose of between 120 and 160mg/L was required. At this dose, treated water color was well above the target level of 6 Pt Co Units.

Figure 10: **Chlorine dioxide, chlorite, and free chlorine vs. time. Water treated at Olga WTP on 7/16/02 with 240 mg/L ferric sulfate. Initial chlorine dioxide dose 1.2 mg/L.**

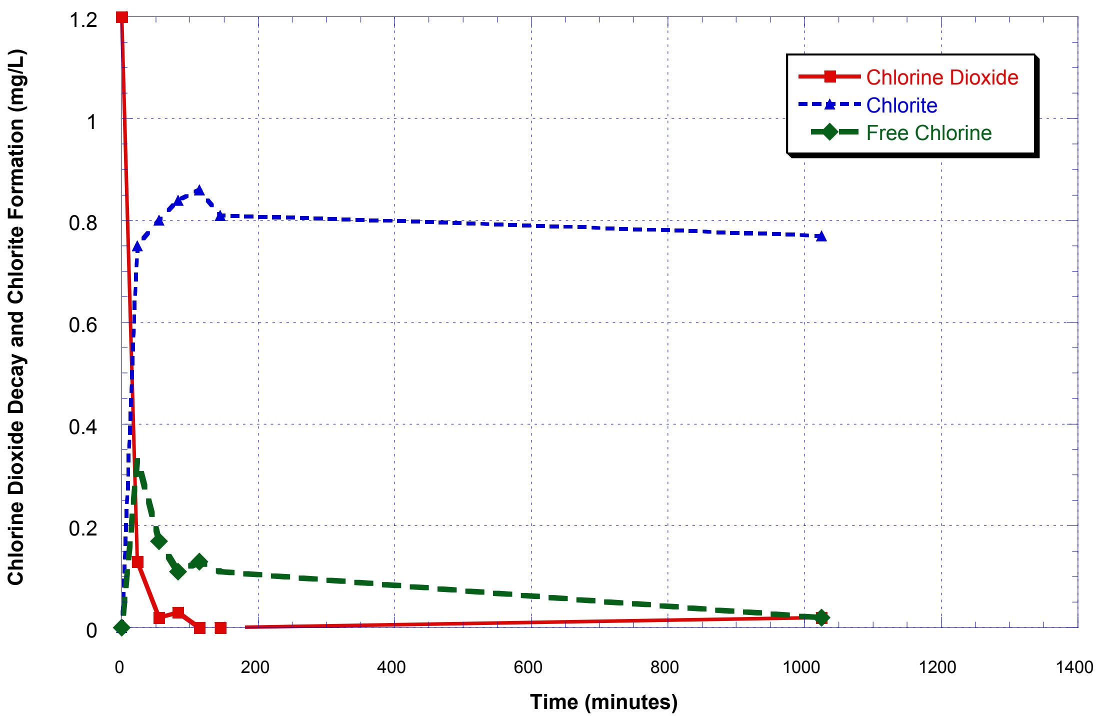


Figure 11: **Chlorine dioxide, chlorite, and free chlorine vs. time. Water treated at Olga WTP on 7/16/02 with 20 ml/L MIEX® and 60 mg/L ferric sulfate. Initial chlorine dioxide dose 1.2 mg/L.**

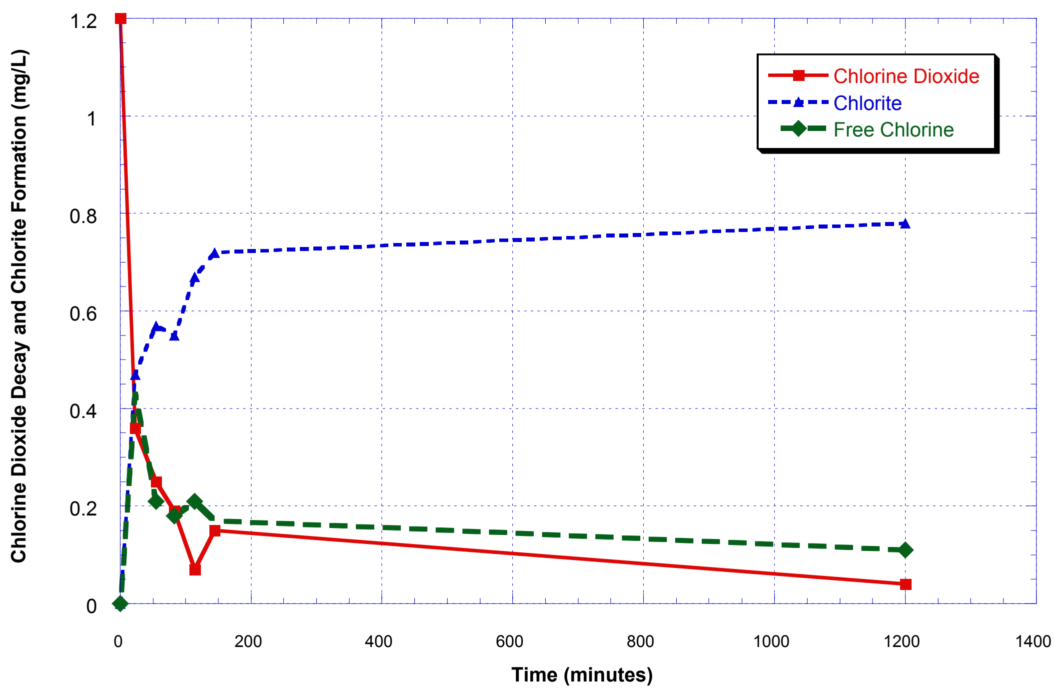
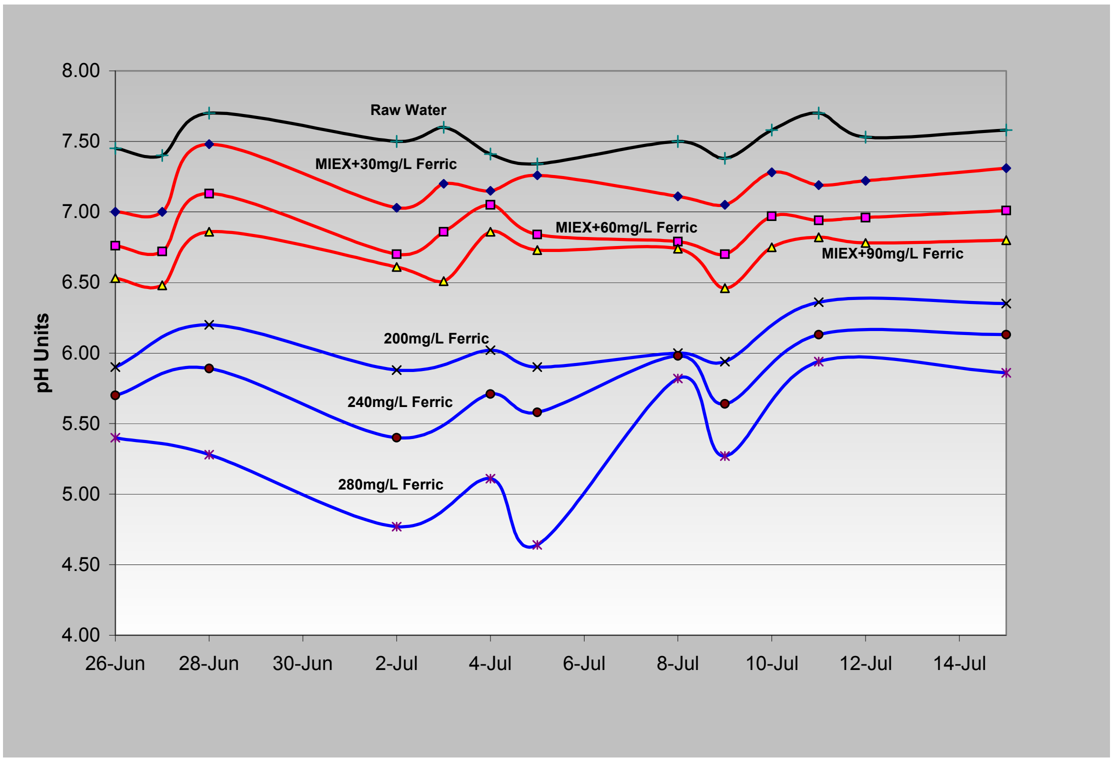


Figure 13: **pH of Various Treatment Regimes**



Conclusions

The major conclusions from the trial conducted from 6/24/02 to 7/16/02 are as follows:

- Despite a significantly higher raw water color due to rainfall over the trial period, all trial objectives were achieved under the following conditions:

MIEX® Resin Concentration:	20 ml/L
Resin Contact Time:	15 minutes
Resin Regeneration Rate:	10%
Ferric Sulfate Dose:	60 mg/L

- A ferric sulfate control dose of 240mg/L was required to achieve the treated water objectives. At this dose the average coagulation pH was 6.0. This is below Lee County's desired minimum level of 6.5 to minimize corrosion of the plant infrastructure. If it is necessary to coagulate at a minimum pH of 6.5 it is likely that the treated water quality achieved with ferric sulfate only will decline. In comparison, the treated water pH of MIEX® treatment followed by 60mg/L of ferric sulfate was 6.9.
- It is possible to reduce THM and HAA formation potentials to well under the EPA Stage 1 Rule Standards using MIEX®/ferric sulfate treatment or low pH enhanced coagulation with ferric sulfate.
- Reductions in ferric sulfate doses of up to 180mg/L were possible after MIEX® treatment which will significantly reduce costs of coagulant, pH correction chemicals and sludge disposal. This represents savings in coagulant costs of almost 15 cents per 1000 gallons. MIEX® system O&M costs are expected to be around 15 cents per 1000 gallons, allowing improved treated water quality without an overall increase in plant O&M costs.
- MIEX®/ferric sulfate treatment will achieve lower treated water DOC levels which will reduce disinfection by-product formation potentials and chlorine/chlorine dioxide demands. This will provide greater flexibility in disinfection at the Olga WTP where target residuals can be maintained at lower disinfectant doses.