

SELECTIVE DBP PRECURSOR REMOVAL WITH AN INNOVATIVE ION EXCHANGE PROCESS

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ABSTRACT

The City of Chesapeake, Virginia has provided a reliable and safe drinking water to its customers for many years. The City has been providing this drinking water despite a water supply that is extremely high in organics with seasonal outbreaks of chlorides.

As a result, the 10-mgd Northwest River Water Treatment Plant receives water that is frequently difficult-to-treat. This water requires very high coagulant dosages during all times of the year and seasonal reverse osmosis treatment to meet the EPA Stage 1 Disinfection Byproduct (DBP) standard for trihalomethanes (THM) of < 80 ppb and haloacetic acids (HAA) of < 60 ppb.

Therefore, to help comply with these regulations as well as reduce sludge generation and overall treatment costs, the City evaluated the magnetic ion exchange resin (MIEX[®]) developed by Orica Watercare. Accordingly, a pilot study was conducted to evaluate the selective DBP precursor removal capability of the MIEX[®] resin in combination with a coagulant. MIEX[®] is a continuous ion exchange process designed to achieve lower THM and HAA standards by removing the TOC fraction that is difficult to remove by conventional water treatment processes.

The major conclusions from the trial were as follows:

- The MIEX[®] resin followed by coagulation provided significantly greater TOC removal (average 80%) compared to the Northwest River WTP (avg 63%).
- Significant reductions in the treated water THM and HAA formation potentials can be achieved with MIEX[®] pretreatment. After treatment with MIEX[®] then aluminum sulfate, the HAA and THM formation potentials were reduced by 53 % and 40% respectively compared to the current WTP output. MIEX[®] followed by alum coagulation provided better compliance with the EPA Stage 1 Standards for THMs and HAAs.
- MIEX[®] pretreatment allowed a greater than 75% reduction in the alum dose to meet the plant TOC removal performance, also reducing sludge production by over 75%.
- The resulting downstream savings in treatment costs after MIEX[®] pretreatment will be \$0.10/kgal. This savings include debt service on the capital improvements for the new MIEX[®] treatment system.

1.0 INTRODUCTION

Chesapeake's primary water source is the Northwest River, which has supplied the Northwest River Water Treatment Plant since 1980. Since its inception, the Northwest River WTP (rated capacity of 10-mgd) has had understandable difficulty treating high levels of organics and chlorides in the raw water supply. Total organic carbon levels in the raw water supply often exceed 25 mg/L and have been observed at levels approaching 70 mg/L.

Accordingly, very high amounts of coagulant (140-190 mg/L or greater as dry alum) are required to control regular TOC levels. In addition, during summer months the high-pressure membranes are operated more frequently to further assist with organic removal to meet the DBP standards as well as treat the seasonal chloride excursions. Finally, the City utilizes chloramination to minimize DBP formation in the distribution system.

The heavy coagulant dosages result in very large sludge volumes that have become problematic. In addition, the reverse osmosis polishing process significantly increases facility operating costs and adversely impacts water rates. Finally, while providing a very stable residual, utilizing chloramination limits the pathogen protection in the treatment processes (ozone is not a disinfectant option due to high levels of bromide).

Therefore, in an effort to improve overall treatability and finished water quality while reducing operating costs, the City chose to evaluate the MIEX[®] resin developed by Orica Watercare. The MIEX[®] resin is a magnetized ion exchange resin used in a pretreatment process to selectively remove TOC from drinking water supplies; thereby, reducing DBP formation potential. A continuous stirred tank reactor (CSTR) is utilized to exchange DOC with the resin. Resin is then fed to a gravity separator where it is recovered, regenerated, and returned to the raw water at the head of the plant¹. In the separator, the fine resin beads magnetically agglomerate into rapidly settling particles, allowing greater than 99.9% recovery of the resin. The MIEX[®] resin proved to provide exceptional TOC removal characteristics in laboratory jar tests as demonstrated by Environmental Health Laboratories (EHL) and the City of Chesapeake. Therefore, to demonstrate continuous, long-term performance of the MIEX[®] resin and develop capital and operating costs estimates for a full scale MIEX[®] system, a Pilot Plant trial was conducted from April 4 to July 13, 2001 at the City's Northwest River WTP.

2.0 METHODOLOGY

The trial was conducted to define the optimum (i.e. most cost-effective) MIEX[®]-alum combination that would not only remove high quantities of organics, but also meet a settled water turbidity of less than 1 NTU. Due to the significantly lower coagulant dosages, the optimum coagulation conditions for the facility would shift. Therefore, careful consideration was required to ensure that the MIEX[®] process would not adversely impact the coagulation process and turbidity removal.

The pilot methodology was designed to evaluate different MIEX[®]-alum dosages and the overall effectiveness for DOC, DBP precursor and turbidity removal as compared to the existing water treatment plant (defined as actual plant performance and simulated plant control jar tests). Accordingly, raw water, MIEX[®] treated water, and alum treated post-MIEX[®] water samples were collected to determine the performance of each step of a MIEX[®]/Alum treatment process.

Each of these samples were analyzed for DOC, UV254, color and turbidity. In addition, the optimum MIEX[®]/alum combination and the plant control jars were also tested for TTHM formation potential and HAA formation potential using a simulated distribution system test. The samples were dosed with free chlorine as a primary disinfectant to maintain a residual of approximately 4 mg/L after 15 minutes. Ammonia was then added to form chloramines and the samples were held for seven days before being quenched and analyzed.

3.0 PILOT STUDY RESULTS

3.1 Raw Water Characteristics

During the trial, the MIEX[®] Pilot Plant was operated in parallel with the Northwest River WTP using the same raw water supply (Figure 1). The raw water characteristics during the trial period are summarized in Table 1.



Figure 1: MIEX[®] Pilot Plant at Northwest River WTP

Table 1: Raw Water Characteristics During Trial

Parameter	Analysis (range)
pH	6.5 – 7.3
Temperature °C	16.0 – 25.0
Total Hardness mg/L CaCO ₃	23 - 52
Color TCU	100 - 262
Dissolved Iron mg/L	0.215 – 0.900
Dissolved Manganese mg/L	0.027 – 0.147
Sulfate mg/L	9.0 – 80
Chloride mg/L	23 - 256
UV Absorbance @ 254 nm	0.806 – 1.27
Total Organic Carbon mg/L	21.6 – 32.2
Specific UV Absorbance (UVabs x 100 / DOC)	3.6 – 4.1

3.2 MIEX[®] Process Operating Parameters

The main MIEX[®] process operating parameters from the trial are summarized below:

Table 2: Summary of MIEX[®] Process Operating Parameters

Parameter	Value
Total Water Treated (gal)	215,000
Actual Flow Rate (gpm)	1.6
Resin Concentration (mL/L)	7-20
Actual Regeneration Rate (%)	10
Regeneration (gal resin / 1000 gal treated)	1.00 –2.00
Waste Produced (gal waste / 1000 gal treated)*	1.2 – 2.3
Salt Consumption (lb NaCl / 1000 gal treated)*	2.1 – 6.0
Rise Rate in Settler	4m/hr
Contact Time (min)	31
Resin Slurry Feed Concentration (%)	15
Resin Dosing Pump Rate (ml/min)	280-700

*Brine regenerant was not recycled during the trial. On a full-scale plant, recycling brine for regeneration will reduce waste volumes and salt consumption.

3.3 TOC and UV₂₅₄ Absorbance Removal

As noted previously, the purpose of the MIEX[®] resin is to selectively remove organics, primarily DBP precursors, from a raw water supply. Obviously, DOC was a primary parameter that was evaluated. In addition, UV₂₅₄ is often used as a surrogate for DOC and DBP precursor potential. Accordingly, UV₂₅₄ was utilized in this pilot to both evaluate performance and quickly identify the optimum performing MIEX[®]-alum combinations for future DBP evaluation.

MIEX[®] treatment followed by alum treatment realized significantly higher DOC removal as compared to the existing plant. On average, the MIEX[®] resin followed by alum coagulation obtained 80% DOC removal, with the best removal being achieved at MIEX[®] dosages of 12-14 mL/L and alum dosages of 30 to 40 mg/L (coagulation pH of 6 to 6.5). By comparison, the plant removes approximately 63% of the raw water DOC with alum dosages of 150 to 220 mg/L. Figure 2 summarizes the results of the DOC data collected during the Pilot Study. Because a wide range of MIEX[®] doses were used during the trial, DOC levels are represented as fluctuations over time. It should be noted that the MIEX[®] process alone typically met the DOC removal of the plant itself at the excessive alum dosage, with the modest alum dosages required for turbidity removal providing the additional DOC removal beyond the existing plant capabilities.

As would be expected, the MIEX[®] resin dose was directly proportional to the DOC removal efficiency. Figure 3 presents the general trend of DOC removal based on the MIEX[®] dosage, and with subsequent alum coagulation of 30 to 50 mg/L. It also compares NW River Plant DOC levels with MIEX[®] and MIEX[®]/Alum treatment. As illustrated, the higher the MIEX[®] dose, the better the performance. In general the MIEX[®]/alum combination with MIEX[®] dosages of 9 to 10 mL/L met the plant's performance while combinations with MIEX[®] dosages of 12 to 14 mL/L significantly beat the plant performance.

As would be expected, the UV254 removal results mimicked the DOC removal discussed previously.

Figure 2: DOC Removal

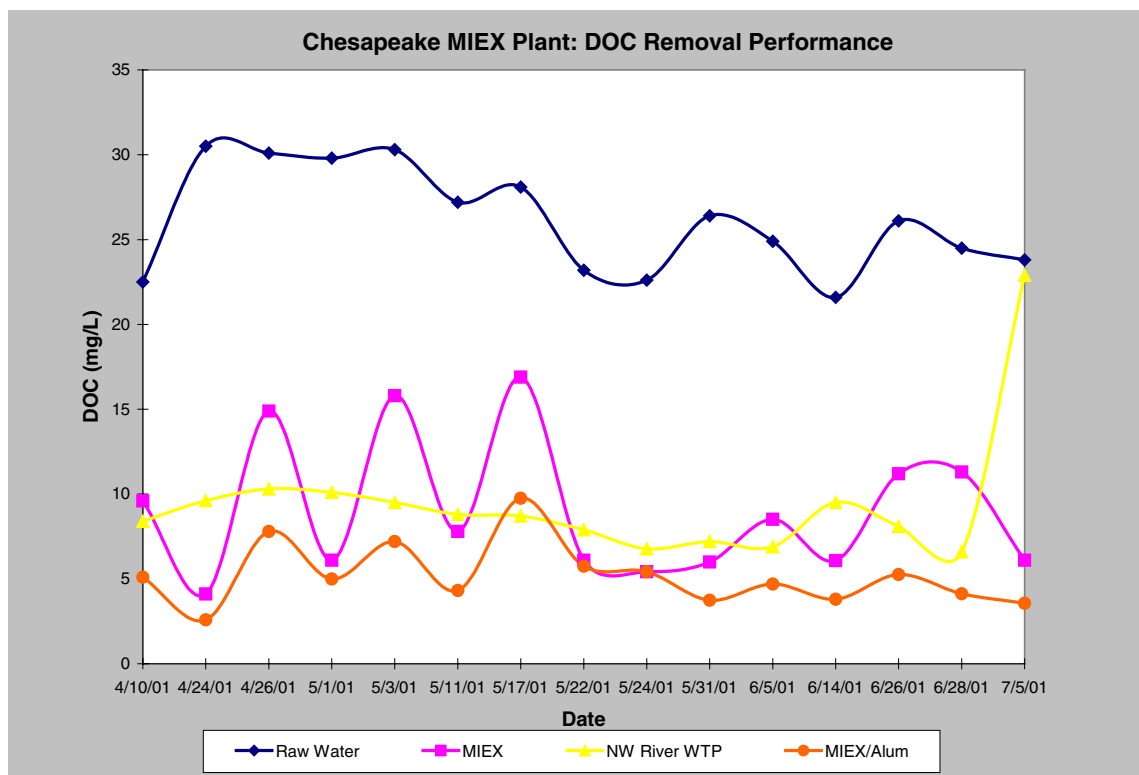
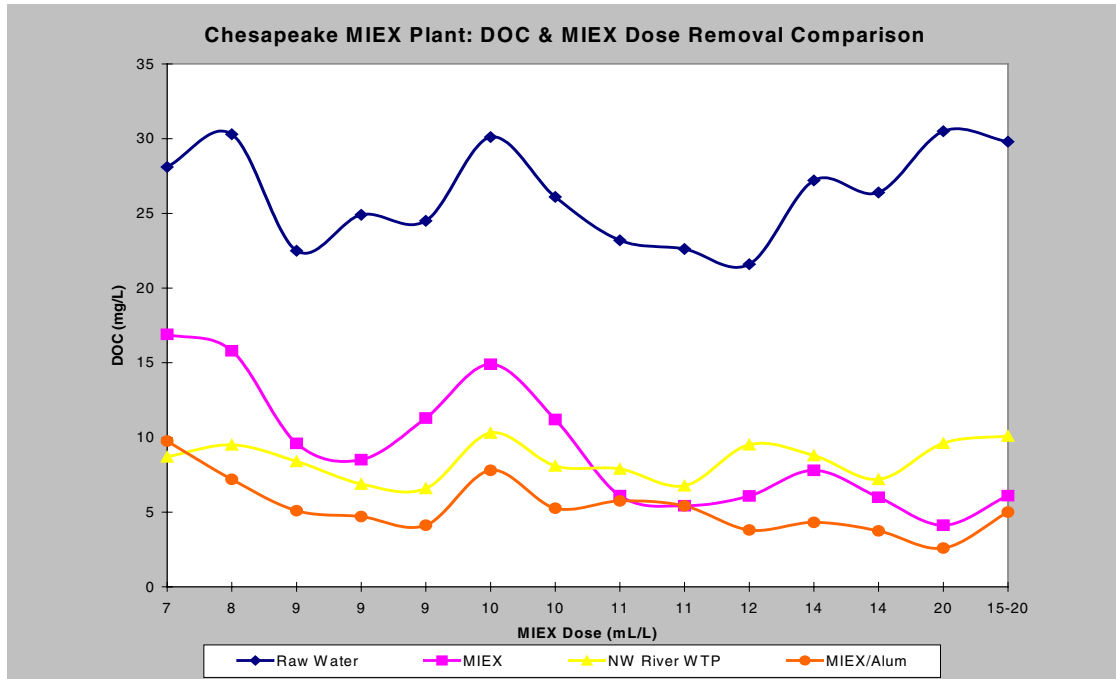


Figure 3: DOC & MIEX Dose Comparison Removal



3.4 DBP Reductions

The disinfection by-product formation potentials followed a similar trend to the DOC and UV₂₅₄ removal results. The MIEX[®]/alum treated water consistently met the EPA Stage 1 TTHM and THAA Standards (upon adjusting the analysis to simulate finished water buffering at the plant), while the alum coagulation alone had difficulty meeting these standards (simulated distribution system DBP methodology). Alum coagulation alone regularly exceeded the Stage I limits by as much as 20%-40% (see Figures 4 and 5). On average, MIEX[®]/alum treatment resulted in a greater reduction in HAAFP (53%) than THMFP (40%) compared to the existing plant performance.

Figure 4: TTHMFP Removal Performance

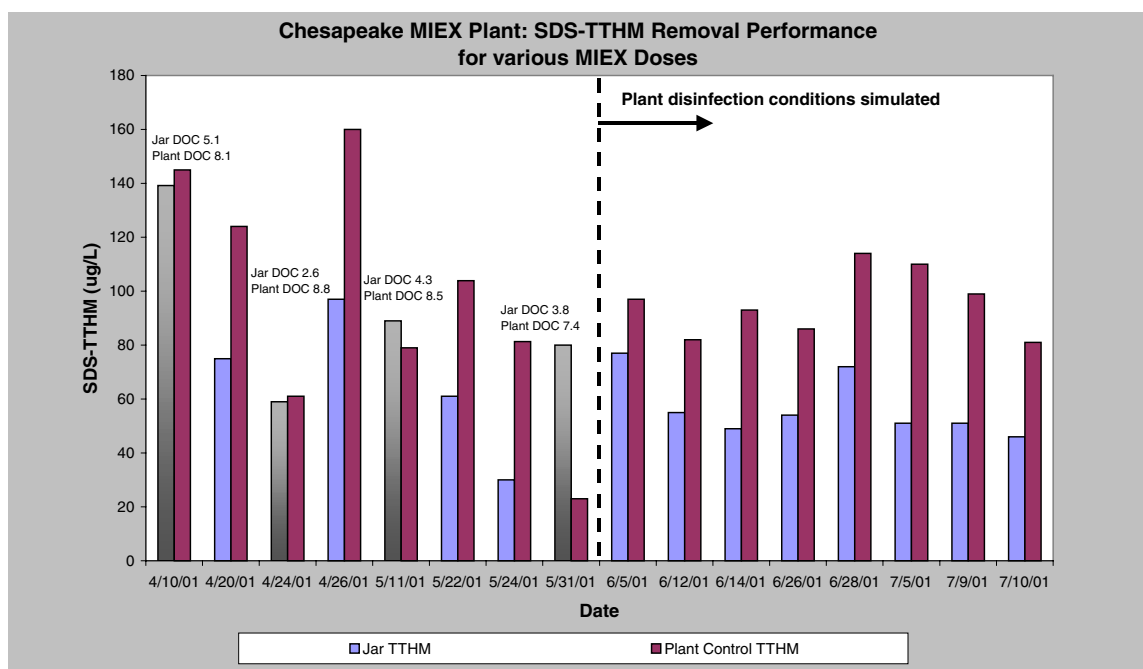
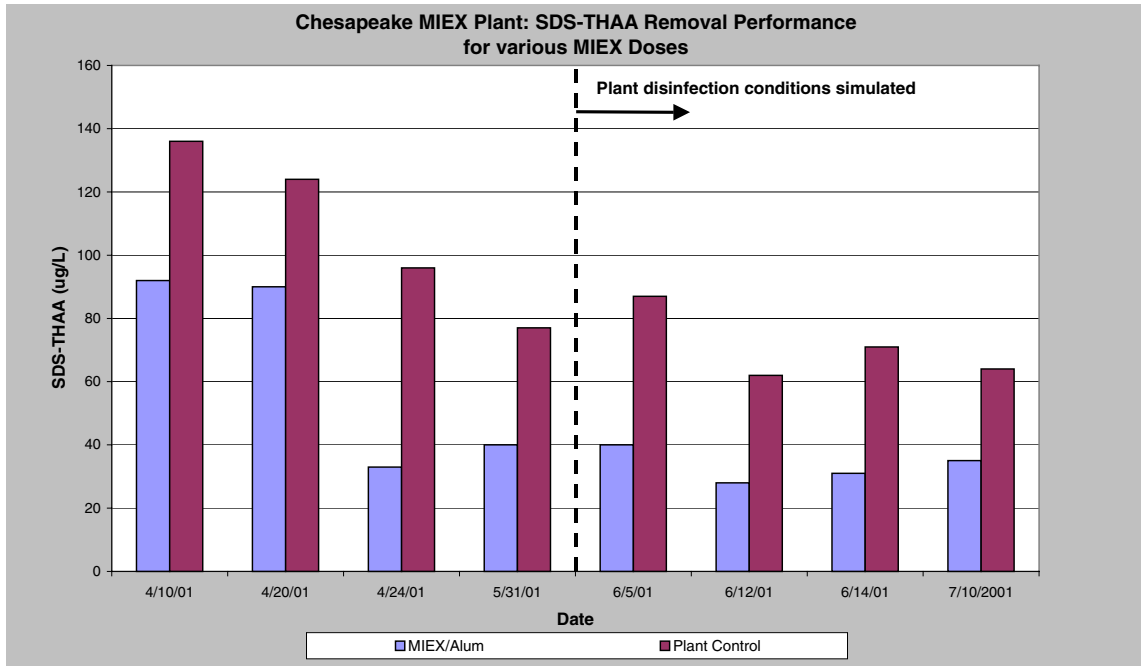


Figure 5: HAAFP Removal Performance



4.0 ESTIMATED MIEX[®] PROCESS OPERATING COSTS

Although the MIEX[®] system provided better treatment in terms of DOC removal and equivalent turbidity removal, it was critical to quantify the cost considerations associated with the MIEX[®] treatment process. The estimated capital cost for the proposed MIEX[®] treatment improvements is \$3 million. It should be noted that this estimate does not include any brine disposal improvements as the plant has an existing concentrate disposal pumping station and pipeline for its existing reverse osmosis treatment facility.

Table 3 presents a cost comparison between the existing plant operation and the proposed MIEX[®] improvements (capital and operating costs). As summarized in Table 3, the proposed improvements will not only improve finished water quality, but will also reduce plant operating costs by approximately \$0.10/kgal.

Table 3: Summary of MIEX[®] Savings

MIEX Dosage:	14 mL/L					
Alum Dosage (w/MIEX):	30 mg/L					
Alum Dosage (plant):	185 mg/L					
Plant Flow Rate:	7 mgd					
MIEX Operating Costs						
	Rate	Units	Unit Cost	Units	Cost/kgal	Cost/yr
Resin Make-Up					\$0.11	\$290,151
Regenerant (NaCl)	0.42	ton/MG	\$50	ton	\$0.02	\$53,655
Power	160	kWh/MG	0.06	kWh	\$0.01	\$24,528
Waste Regenerant Disposal (750 gal/MG)	750	gal/MG			0	
TOTAL OPERATING COSTS					\$0.14	\$368,334
MIEX Capital Costs						
Capital Costs Equipment (\$2.50 million)	6, 20	%, years	\$3,000,000	--	0.10	\$259,500
Capital Costs - Resin (30 minute CT @25% Fresh)	14	mL/L	\$315,000	ml/L	0.01	\$27,248
TOTAL CAPITAL & OPERATING COSTS					\$0.26	\$655,081
MIEX Savings						
	Unit Cost	Units	Dose Reduction	Units	Savings (\$/kgal)	Savings (\$/yr)
Liquid Alum, 48%	\$111.94	dry ton	155	mg/L	\$0.07	\$184,860
Caustic Soda, 25%	\$138	wet ton	15	mg/L	\$0.01	\$22,055
Chlorine, 12%	\$0.73	gal	3	mg/L	\$0.02	\$46,616
Chemical Sludge Disposal	\$287	ton	239	lbs/MG	\$0.03	\$87,690
Polymer	\$1.22	lb	0.03	mg/L	\$0.00	\$780
RO Operation	\$0.75	kgal	30	%	\$0.23	\$574,875
TOTAL ESTIMATED SAVINGS					\$0.36	\$916,876

5.0 CONCLUSIONS

Based on the results of this pilot study, the following conclusions were drawn:

- The MIEX[®] resin is a very effective alternative to a conventional coagulation process for organics and DBP precursor removal.
- The MIEX[®] resin can significantly reduce coagulant dosages resulting in corresponding reduced sludge production.
- In addition to reduced alum dosages, the MIEX[®] resin can help reduce usage of caustic soda (for pH correction) and disinfection chemicals.
- MIEX[®] is a very cost effective alternative to reverse osmosis or nanofiltration for enhanced organics and DBP precursor removal.
- MIEX[®] treatment can significantly reduce TTHM and HAA formation potential.
- Increased MIEX[®] dosages can provide additional DOC removal.
- Brine discharge disposal is critical and cost-effective disposal is important for overall cost effectiveness.
- For this application, the MIEX[®] process followed by alum resulted in a cost savings of approximately \$0.10/kgal, or approximately \$260,000 per year.

6.0 REFERENCES

¹ Slunjski M, Bourke M, O'Leary B, *MIEX[®] DOC Process for Removal of Humics in Water Treatment*, IHSS-Australian Chapter Seminar, (February 2000).