WHITE PAPER

Use of the MIEX® Process for DBP Compliance at Three Installations in Ohio: From Bench Test to Full Scale Operations

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Executive Summary

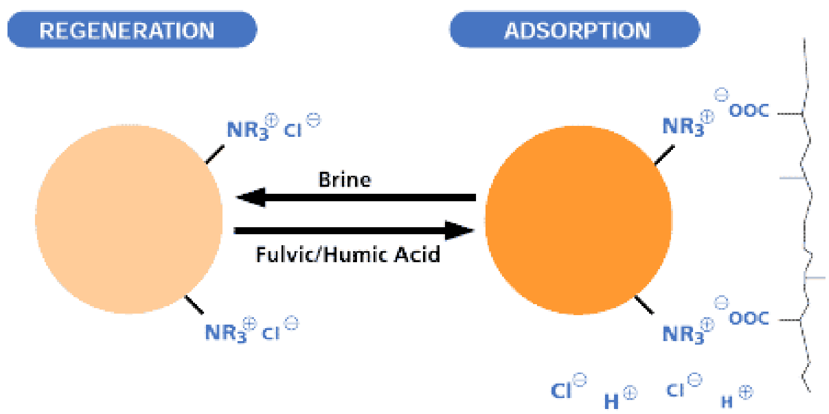
A large proportion of the state of Ohio's drinking water supplies consists of surface water treated by conventional treatment technologies. With introduction of the EPA Stage 1 Disinfection Byproducts Rule (DBPR), many water supplies were found to be out of compliance due to the inability of conventional treatment to remove enough dissolved organic carbon (DOC) prior to free chlorine disinfection. In 2006 there were 64 systems in Ohio out of compliance with the Stage 1 DBPR. Without changes to treatment processes or disinfection practices, many more water supplies will be out of compliance when the more stringent Stage 2 DBPR is implemented in 2012.

Currently three Ohio systems have installed MIEX® Systems for TOC removal to ensure compliance with current and future DBP standards. Two of the systems were previously out of compliance with the Ohio EPA disinfection by product (DBP) regulations while the third, though in compliance with Stage 1 using a costly chemical treatment regimen, was certain to be out of compliance when Stage 2 was introduced. This paper takes an in-depth look at the MIEX® Process, and compares each Ohio system's laboratory and pilot evaluations to ongoing performance of the full-scale MIEX® Systems.

Ion Exchange for Organic Carbon Removal

A large percentage of the DOC in natural water sources is polar (hydrophobic, transphilic and hydrophilic), and therefore can potentially be removed by anion exchange (Owen, 1993). Anion exchange resins remove DOC by exchanging a chloride ion on the resin surface for polar dissolved and colloidal organic material (Figure 1). These resins can then be easily regenerated with sodium chloride solution. Numerous studies have shown that ion exchange preferentially removes high charge density, medium-to-low molecular weight (MW) organic material, which can consist of hydrophobic, transphilic and hydrophilic organic fractions (Pyles 2008; Bourke, 2009).

Figure 1: DOC Removal by Ion Exchange



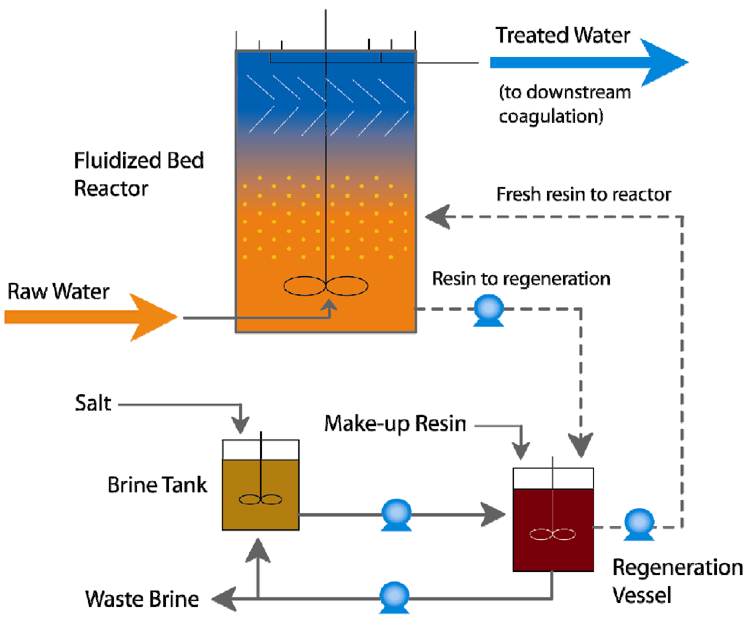
Traditionally, ion exchange has not been used at water treatment plants for pretreatment due to turbidity blocking the resin bed and biological activity fouling the resin. The development of mixed bed and fluidized bed ion exchange systems has now made it possible for this technology to be used for DOC removal when turbidity is present.

The MIEX® Process utilizes anion exchange resin beads that contain a magnetized component within their structure, allowing them to act as weak individual magnets. These magnetic particles form rapidly settling agglomerates, enabling application under mixed and fluidized bed conditions, allowing the process to be relatively unaffected by the presence of suspended solids. The very small resin bead size of around 200 µm provides a high surface area facilitating rapid ion exchange kinetics. A fluidized bed ion exchange reactor removes DOC while allowing turbidity to pass through the reactor for downstream removal (Figure 2). The magnetized anion exchange resin is continually withdrawn from the reactor for regeneration and at the same time is replaced by fresh regenerated resin to maintain consistent removal of the target anion (DOC in this case) with no risk of chromatographic peaking (contaminant dumping). The continual regeneration of resin in brine also minimizes any biological growth within the ion exchange process. The resin can be regenerated using sodium chloride, sodium bicarbonate or potassium chloride. The volume of waste regenerant produced is typically less than 0.1% by volume of the total treated flow.

Downstream Benefits

The MIEX® Process is most commonly applied as the initial treatment process in a surface water treatment plant. This is due to the fact that there are a number of downstream process benefits that occur as a result of reducing the DOC level, particularly with regards to coagulation (Jarvis, 2008). By removing hydrophobic compounds, the subsequent coagulant demand is significantly reduced. Anion exchange can also remove low to medium molecular weight organics, which tend to be less effectively removed by coagulation, therefore resulting in lower DOC levels in the final treated water (Pyles, 2008). Lower final DOC levels result in a lower chlorine demand and reduced formation of disinfection by-products.

Figure 2: MIEX® Process Flow Diagram



This reduction in coagulant dose after MIEX® Treatment has been demonstrated in full-scale installations, including the three Ohio installations. The ability to reduce coagulant dose results in many associated treatment benefits. In low alkalinity water where significant amounts of pH adjusting chemicals are added in addition to a coagulant, the requirement for these chemicals will be reduced along with the coagulant dose. The coagulant dose reduction will also result in less chemical sludge being produced by the treatment plant. Often a faster settling floc has been observed after pretreatment with the MIEX® Process (Jarvis, 2008) resulting in reduced turbidity in the clarifier effluent and less solids loading on the filters. Plants may therefore also experience longer filter run times and improved operability.

Ohio Operating Plants

Currently three full scale MIEX® Systems are operating in Ohio at Portsmouth, Burr Oak and Napoleon. All three systems were commissioned in 2008 ranging in capacity from 2.4 MGD to 7.5 MGD.

Case 1: Portsmouth WTP

The City of Portsmouth draws its drinking water from the Ohio River. The Portsmouth WTP is rated at 15 MGD although currently has an average throughput of 5-6 MGD. Although in compliance with the Stage 1 Disinfection by Product Rule (DBPR), the plant was not meeting the EPA TOC treatment technique requirement, averaging only 13% TOC removal where 35% is required. The City was also confident it would not meet the locational limits for DBPs required under the future Stage 2 DBPR. The MIEX® Process was first evaluated by the City in a batch test at the WTP in June 2003. These tests demonstrated that a significant improvement in TOC removal could be achieved and this was confirmed in a subsequent trial conducted during October 2003 using a 5 gallon per minute MIEX® Pilot plant. Following the trial, with a desire to meet Stage 2 limits as early as possible, a decision was made to install a 7.5 MGD MIEX® System. Commissioning of this system occurred in June 2008 just prior to the City commencing the EPA's Initial Distribution System Evaluation (IDSE) monitoring to determine sample points for future compliance with Stage 2. Table 1 summarizes the laboratory evaluation results and the WTP performance prior to and after MIEX® System start-up.

Table 1: Portsmouth WTP Results

Treatment	Raw DOC (mg/L)	Finished DOC (mg/L)	Avg. DOC Removed	TTHM (µg/L)	HAA5 (µg/L)
June 2003					
MIEX® Bench Test	2.65	0.85	68 %		
July 2007 – July 2008				Individual Range	
Full-scale: Before MIEX® Start-up	4.1 – 2.9	2.9 – 2.4	15 – 30%	17 – 102	14 - 28
October 2008 – June 2009				Individual Range	
Full-scale: After MIEX® Start-up	5.3 – 2.9	2.6 – 1.0	50 – 65%	16 – 50	11 - 21

The Portsmouth WTP is currently finishing monitoring under the IDSE provision of the DBP Stage 2 Rule. During this evaluation (September 2008-2009), not a single IDSE or regular monitoring site has exceeded the TTHM limit of 80 µg/L or the HAA limit of 60 µg/L.

There have been numerous additional benefits in addition to DBP reductions seen at the Portsmouth treatment plant. Chemical use has been dramatically decreased. The alum and lime doses have been reduced by 50 percent and the chlorine dose by 30 percent. The potassium permanganate has been turned off as well as the powdered activated carbon (PAC), both which had formerly been used to maintain compliance with the Stage 1 DBPR. It also was noted that the WTP did not experience any taste and odor events during the 2008-2009 season where occasional events typically require PAC dosing.

Each sedimentation basin requires manual cleaning for sludge removal. This process used to take an entire day of blasting with a fire hose to clean out a single basin. Due to reduced coagulant dosing, this process now takes about two hours, saving many thousands of gallons of water and hours of labor.

Case 2: Burr Oak WTP

The Burr Oak Regional Water District, BORWD, in Glouster, Ohio is a water wholesaler whose 2.4 MGD water treatment plant serves nineteen satellite systems. While TTHM levels were within the EPA standard leaving BORWD, these levels increased within its customers' distribution systems resulting in six of the retail water systems exceeding the Stage 1 TTHM MCL.

BORWD sources its raw water from the Burr Oak Reservoir. Treatment consisted of conventional coagulation with alum and a polymer. Sodium permanganate and powdered activated carbon were also added to the raw water in an attempt to improve the TOC removal. Raw water TOC levels, in the range of 2.7 to 4.4 mg/L, were reduced by an average of 40 percent through the conventional treatment process. In addition to chlorination at the water treatment plant, six of BORWD's customers had chlorine booster stations to maintain an adequate residual. The longest detention time to these customers is in the range of 14 to 15 days.

BORWD first evaluated the MIEX® Process in March 2007. Since the WTP was under consent decree from OEPA, a decision was made to proceed with a full-scale installation following successful bench scale testing without running a pilot trial. A 2.4 MGD MIEX® System was brought on-line in May 2008.

Table 2: Burr Oak WTP Results

Treatment	Raw TOC (mg/L)	Finished TOC (mg/L)	Avg. TOC Removed	TTHM (µg/L)
March 2007				
Jar Test	3.8	1.2	68 %	
2007 – May 2008				Distribution Max
Consecutive Systems before MIEX® Treatment	3.3	1.9	42%	159
October 2008 – June 2009				Distribution Max
Consecutive Systems after MIEX® Treatment	3.7	1.4	62%	61.4

Since the MIEX® System was installed a significant reduction in treatment chemicals has been realized (See Table 3). Floc settleability has greatly improved with a subsequent 50 percent reduction in turbidity levels going onto the filters. The lower treated water TOC level has significantly reduced the chlorine demand in the distribution system, allowing all six chlorination booster stations to be turned off.

Table 3: Summary of downstream benefits after MIEX® System Start-up

Parameter	Before	After
TOC % Removal (avg)	10-59 (40)	51-68 (62)
Permanganate Dose (mg/L)	1.5	0
Alum Dose (mg/L	35	8
Chlorine dose (mg/L)	2.9	2.1
Booster Stations in Use	6	0

Case 3: Napoleon WTP

Prior to late 2008, the City of Napoleon's conventional WTP regularly exceeded the Stage 1 DBPR TTHM limits. The WTP draws raw water from the Maumee River in Northwest Ohio. Laboratory scale treatability studies of the MIEX® Process were conducted in November 2003 and July 2004 evaluating the percent removal of ultraviolet absorbance at 254 nanometers. Following a successful pilot trial conducted during August 2004, the City proceeded with installing 4.5 MGD MIEX® System which started up in October 2008. Since start up of the MIEX® System, TTHMs have been reduced by more than 50 percent. Not only is the City now complying with the Stage 1 DBPR but additionally will be in compliance with the Stage 2 DBPR. Table 4 summarizes the laboratory and pilot studies and full-scale results for the Napoleon WTP.

Table 4: Napoleon WTP Results

Treatment	Raw TOC (mg/L)	Finished TOC (mg/L)	Avg. TOC Removed	TTHM (µg/L)	HAA5 (µg/L)
July 2004				SDS	
MIEX® Process Jar Tests	8.0	2.5	68 %	61.9	NA
August 2004				SDS	
Pilot Trial	7.4	2.5	66%	59	31
Annual 2008				RAA Dist. System	
Full-scale: Before MIEX® Start-up	7.4	2.7	63%	86	35
Jan 2009 – June 2009				RAA Dist. System	
Full-scale: After MIEX® Start-up	6.8	1.6	73%	37	19

Conclusion

The introduction of tighter EPA standards for disinfection byproducts had required many water treatment systems, particularly those with surface water supplies, to look for treatment technologies to improve DOC removal to remain in compliance. Ohio has been particularly impacted with many water supplies relying on surface water sources.

The MIEX® Process is an anion exchange process for DOC removal that has the ability to reduce raw water DOC levels by up to 90%. It is typically applied as the initial treatment step in a surface water treatment plant, due to the fluidized bed configuration of the process, which is not affected by the presence of suspended solids in the raw water. The preferential removal of low to medium molecular weight DOC compounds, that tend to be reactive with chlorine but are not removed by coagulation, results in significantly reduced formation of DBPs. Additionally, the removal of these portions of the organic matter tends to complement conventional coagulation processes, which removes a different fraction of the organic matter, resulting in reduced dosages of chemicals required downstream of ion exchange treatment.

The MIEX® Process has been proven to be an effective solution for meeting current and future DBP regulations at three full-scale water plants in Ohio and many more across the United States. Each of the Ohio MIEX® Systems has matched or exceeded the performance of bench and pilot scale analyses, achieving current and future DBP compliance while reducing the plants' dependency on chemical treatment.

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