MIEX® Resin Pretreatment Followed by Microfiltration as an Alternative to Nanofiltration for DBP Precursor Removal

Michael Bourke, US Market Manager, Orica Watercare, Denver

Stuart Harrison, Senior Process Engineer, Orica Watercare, Melbourne, Australia

Bruce Long, Director, Water Treatment Technology, Black & Veatch, Kansas City

Thomas Lebeau, Senior Development Engineer, US Filter, Sydney, Australia

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Introduction

While microfiltration (MF) and ultrafiltration (UF) are seen as effective technologies to provide compliance with the EPA's future microbial standards, they provide very little NOM removal, and therefore without any pretreatment are not appropriate for raw water supplies that currently do not meet the Stage 1 or Stage 2 Disinfection By-Product Rule (DBPR).

Nanofiltration (NF) is being considered by many water utilities as a means of meeting the EPA Stage 1 and 2 DBPR when enhanced coagulation cannot remove a sufficient amount of NOM to meet the trihalomethane (THM) and haloacetic acid (HAA) standards. Pretreatment with coagulants or powdered activated carbon (PAC) prior to MF or UF can provide NOM removal but drawbacks include reductions in membrane flux rates and increased backwashing requirements. The requirement to optimise coagulant dosage also adds a degree of complexity to the MF or UF treatment system. On some water supplies, coagulants and PAC are not able to remove enough NOM to meet the future DBP standards. MF/UF treated water will therefore require further treatment with ozone and granular activated carbon (GAC) to remove enough DBP precursors for Stage 1 compliance, resulting in a complex and expensive treatment train.

Trials in Australia have shown that MIEX® resin, used in a continuous ion exchange process, is highly effective at removing low and medium molecular weight NOM and can achieve greater removals of NOM than enhanced coagulation[1]. When used as a pretreatment step, up to 80% of raw water NOM can be removed prior to MF or UF, resulting in removals of DBP precursors that are competitive with NF.

A trial was conducted in Sydney, Australia using MIEX® treatment upstream of microfiltration. The primary objective of this trial was to determine the impact of MIEX® resin pretreatment on membrane flux rates and cleaning requirements.

This treatment regime has also been successfully trialed by the South Australian Water Corporation where MIEX® pretreatment removed 50-60% of raw water NOM prior to microfiltration. A full scale plant utilizing this combined process is now under construction in South Australia and due for commissioning in early 2001.

This paper discusses the results of the Sydney trial as well as the applicability of the MIEX®/microfiltration treatment regime in the United States for meeting the future EPA DBP standards. Cost comparisions are also made for this treatment regime versus nanofiltration.

Background

The MIEX® resin was developed in Australia specifically for the removal of dissolved organic carbon from drinking water sources. The MIEX® resin is a micro size, macroporous, strong base, magnetic ion exchange resin, developed for the reversible removal of negatively charged organic ions. These characteristics result in a resin that is highly resistant to physical attrition and organic fouling.

The resin also has a very small particle size with a mean particle diameter of only 180µm. While the specific surface area is comparable to other conventional macroporous resins, the MIEX® resin has a lot more external bead surface area. This benefits the DOC exchange kinetics (less controlled by particle diffusion) and the resistance to fouling (less DOC exchanged into the particles due to shorter diffusion paths within the smaller beads)[2].

In addition to these features, the resin has a magnetic component incorporated into its polymeric structure. This makes individual resin beads behave like small magnets capable of forming large, heavy agglomerates. This special feature is where the MIEX® name is derived – **M**agnetic **I**on **EX**change and it enables the resin to be applied in a unique process.

The MIEX® resin is applied in a continuous ion exchange process where the ion exchange occurs in mixed tanks. A very small amount of resin (5-15 mls of settled resin per liter of water) is used to exchange organics from water during a 10-30 min detention time in a continuous, stirred tank reactor. The resin is then separated in a gravity settling basin and treated water overflows to further downstream treatment. Gravity separation of the resin is very efficient because of "magnetically" enhanced agglomeration of individual resin beads, a process that yields resin agglomerates capable of settling against high water rise rates in the settler. Settled resin is pumped back to the contactor as a concentrated slurry. A small amount of recycled resin is continuously removed for regeneration and replaced with regenerated resin (see Figure 1).

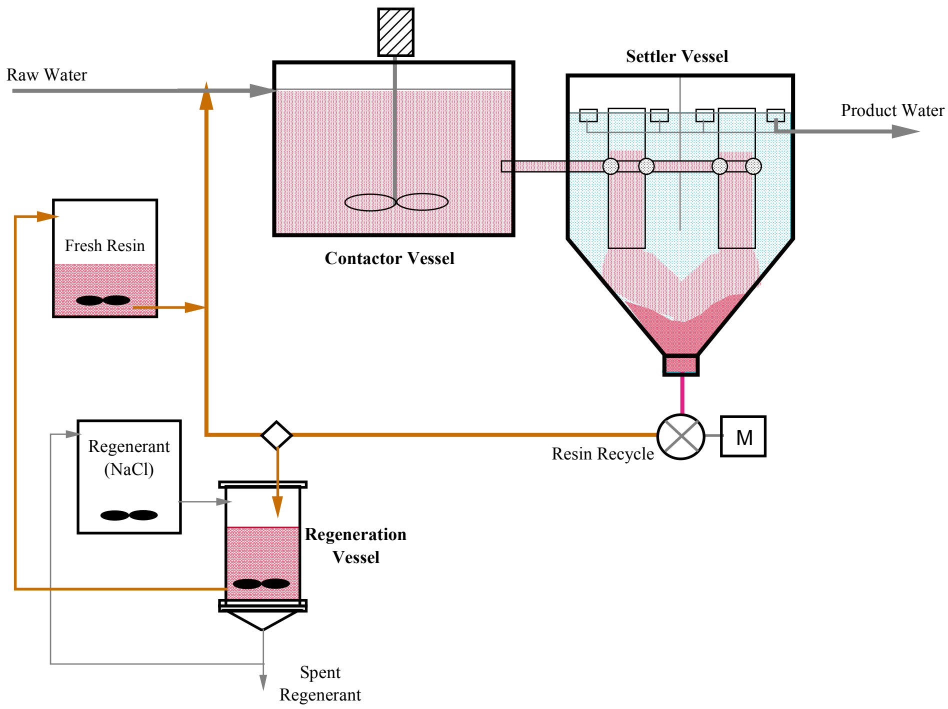


Figure 1: Flow Diagram of MIEX® Continuous Ion Exchange Process

MIEX® Pretreatment Prior to Membranes

An advantage of the MIEX® system over conventional ion exchange columns is that it can be used to directly treat raw water, unaffected by high levels of turbidity that do not accumulate in the gravity separator at the high surface loadings used. The MIEX® treatment system only removes dissolved compounds from water and therefore some form of filtration must follow the process to remove any turbidity and carryover resin in the water, and also act as a barrier to micro-organisms.

Most of the NOM and color in water supplies will pass through low pressure membranes (MF & UF)[3]. If removal of these compounds is required, some form of pretreatment is necessary. Depending on the characteristics and concentration of the NOM, conventional coagulation or powdered activated carbon dosing prior to MF or UF may achieve the required amount of NOM removal. This method of pre-treatment can be problematic for some membrane systems where coagulant residuals and an increased solids loading can reduce membrane fluxes and increase cleaning requirements. The relatively "clean" membrane plant will now also produce a chemical sludge that requires disposal. Nonetheless, in many situations this treatment regime will be the most cost effective for a utility if NOM levels can be lowered sufficiently.

There are many water sources, particularly in the South East and Mid Atlantic regions of the US, where coagulants cannot achieve the required NOM removal due to the characteristics of the NOM. Coagulants are effective at removing the high molecular weight fraction of NOM but remove very little of the lower molecular weight fraction. Research shows that MIEX® resin preferentially removes the low to medium molecular weight fraction that is not removed by inorganic coagulants even at very high coagulant doses. This has been demonstrated on a groundwater source in a trial at Wanneroo, Perth, Western Australia (Figure 2)[1].

Recently performed studies on US waters have also demonstrated that MIEX resin can remove a greater fraction of NOM than enhanced coagulation (Figure 3)[4,5].

Therefore, where NOM in a raw water source is predominantly of low to medium molecular weight, MIEX® is likely to be a more effective pretreatment stage for MF or UF than coagulation.

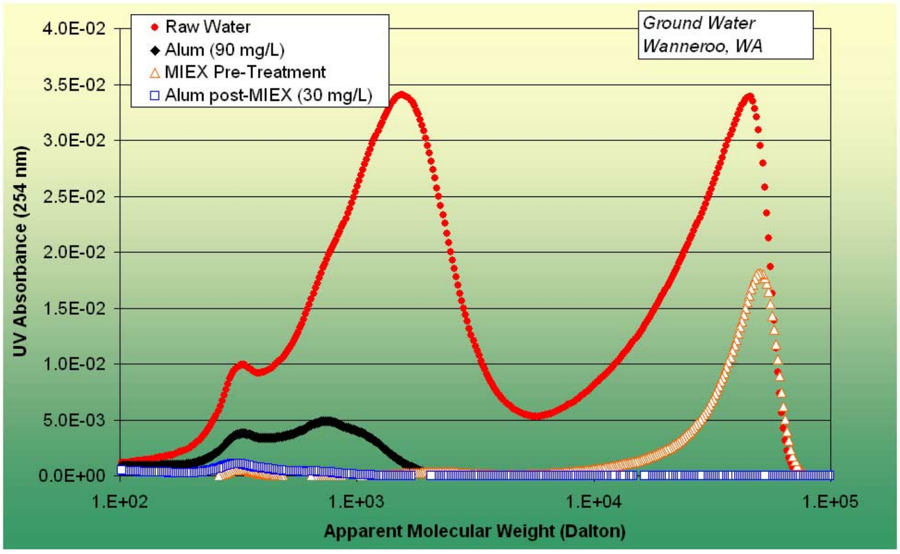


Figure 2: Characteristics of NOM Removed with MIEX® resin and Alum on Wanneroo Ground Water, Western Australia.

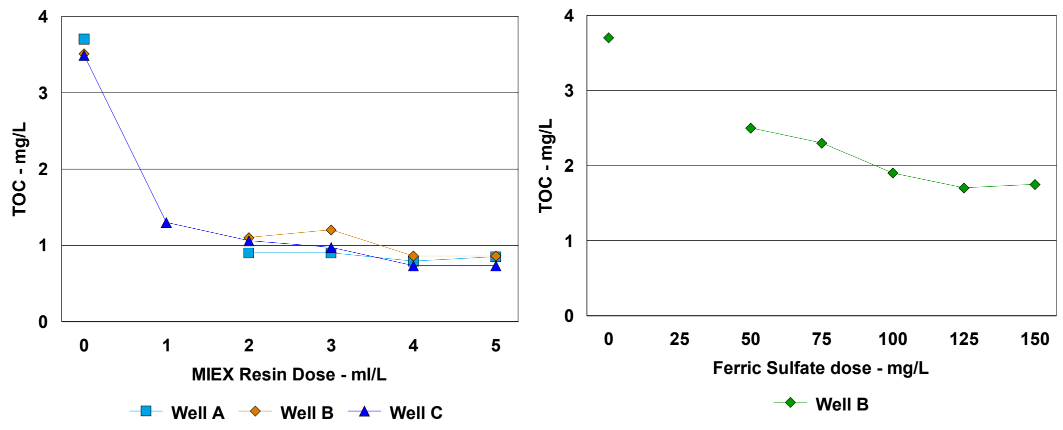


Figure 3: TOC Removal with MIEX® Resin versus Enhanced Coagulation on Pasco County FL Groundwater[4].

The introduction of immersed membrane technology has made it possible to utilize existing plant infrastructure, keeping capital costs down for both small and large water treatment plants. Where current coagulation practices cannot provide compliance with the future DBP regulations, MIEX® can be used as a pretreatment process or, where the water quality and plant configuration is suitable, be retrofitted along with membranes into the existing infrastructure to keep capital costs to a minimum (See Figure 4).

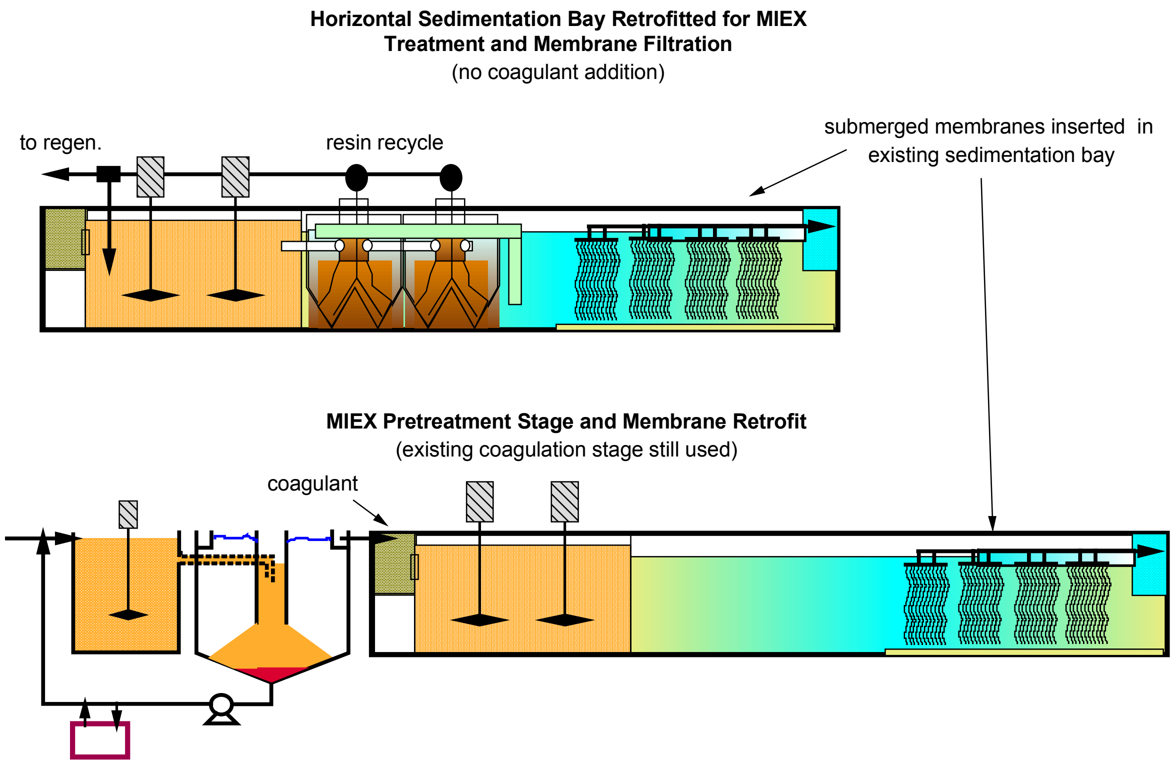


Figure 4 : Potential MIEX®/Membrane Configurations

MIEX®/Microfiltration Trial in Sydney, Australia

Trial Objectives

A trial was conducted in Australia from Feb 16 to June 9, 2000 at US Filter's Memfarm site in Sydney, Australia where a 9.2 gpm MIEX® pilot plant was used to pretreat raw water from nearby South Creek prior to treatment in a 4.6 gpm submerged microfiltration (CMFS) unit. This site was chosen because US Filter had significant experience with the performance of its membrane systems on this water source and would therefore be able to gauge what impact MIEX® pretreatment had on membrane peformance.

The objectives of this trial were;

- Determine the impact on membrane flux rates and cleaning frequency after removal of dissolved organic carbon (DOC) with MIEX® resin.
- Establish if carryover resin from the MIEX® pilot plant had any adverse impact on membrane performance.
- Observe the practicality of operating the two automated pilot plants in series.

Pilot Plant Operation

The MIEX® pilot plant was operated using a constant resin concentration of 10 mL/L in the contactor and a contact time of 30 minutes. Treated water passed from the resin settler to a break tank prior to microfiltration. From the break tank, 4.6 gpm of the MIEX treated water was transferred by submersible pump to the CMFS unit (Figure 5). During the trial runs, the CMFS unit operated with two flux rates of 80 and 100 L/hr/em. The membranes used consisted of conventional polypropylene fibres. Backwash frequency during the trial was every 20 minutes. CIP's were performed as necessary.

South Creek's water quality can vary widely with factors such as rainfall and sewage treatment plant effluent contributing to water quality. Five small sewage treatment plants upstream from Memfarm contribute to South Creek. The raw water received no treatment prior to going to the MIEX® pilot plant. During the trial, raw water characteristics fell within the following range:

DOC:	4.0 - 12.5 mg/L
Colour:	15 - 135 Hazen Units
UV_{254} abs:	0.140 - 0.75
Turbidity:	25 - 200 NTU

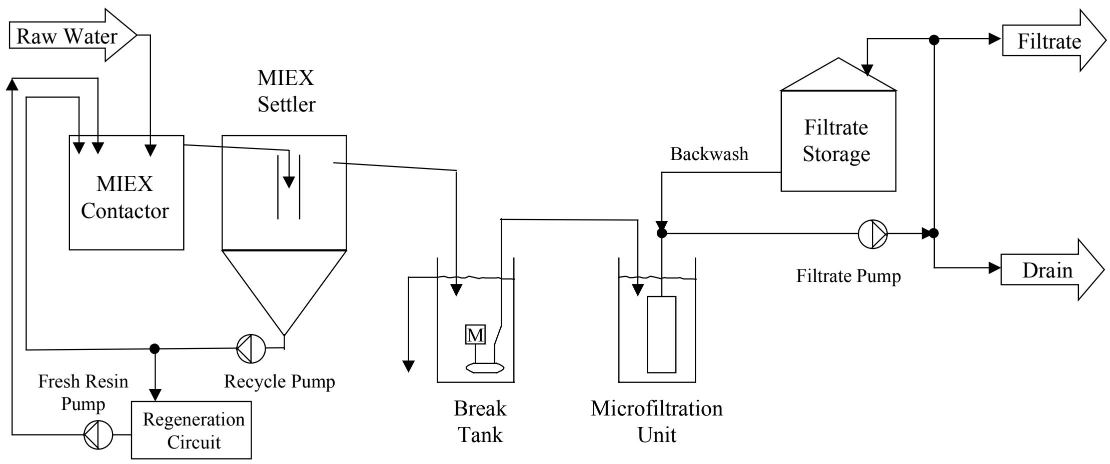


Figure 5: MIEX®/CMFS Trial Set-up

Trial Results

Figure 6 shows the turbidity of the raw water during the trial. The process experienced wide turbidity fluctuations with very high turbidities in March due to high levels of rainfall in the Sydney area. The high rainfall also led to increased DOC, UV_{254} absorbance and color levels as shown in Figures 7, 8 & 9 respectively.

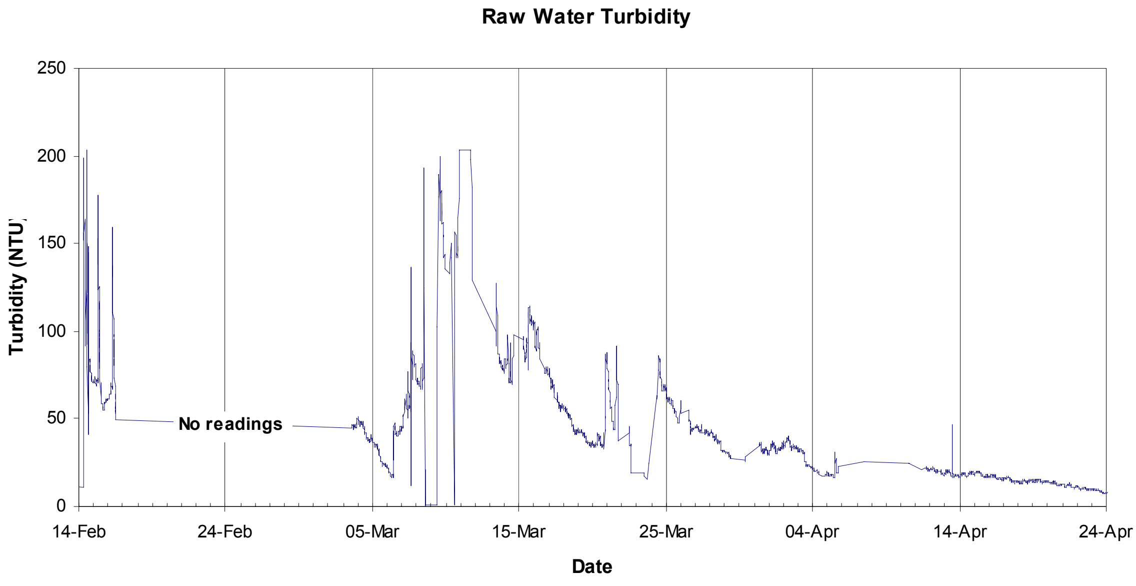


Figure 6: Raw Water Turbidity During MIEX®/CMF Trial

During the periods of high turbidity, DOC and color, the MIEX® resin concentration was not altered as the main objective of the trial was to investigate the impact on microfiltration operation rather than optimise DOC and color removal. The percent DOC and color removal achieved throughout the trial was therefore constant and treated water levels followed the trend of the incoming raw water.

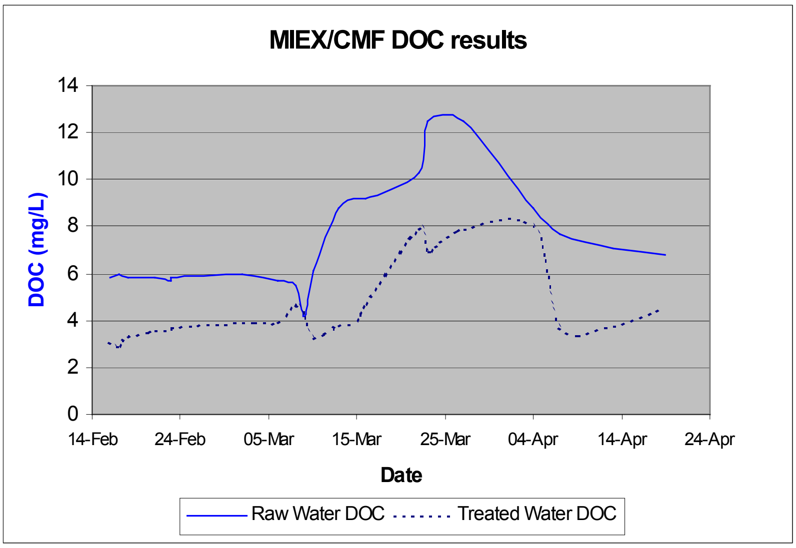
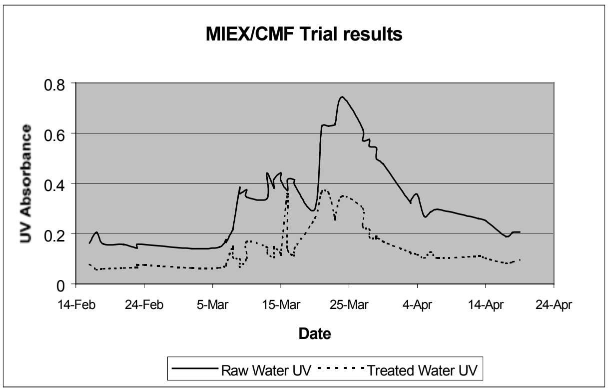


Figure 7: Raw and treated water DOC levels

Even though high turbidities were experienced during the trial no impact on resin performance was observed. In addition to this, high turbidities did not lead to an accumulation of solids in the resin recycle line.



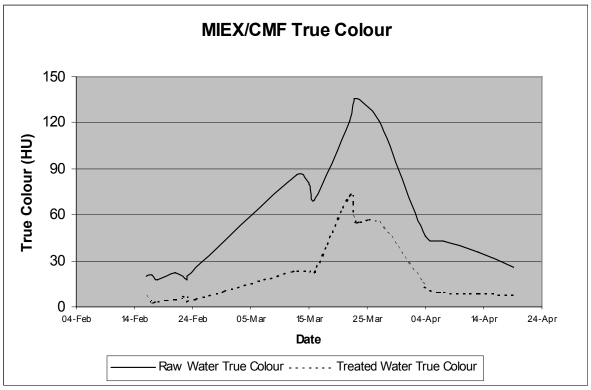


Figure 8: Raw and treated water UV_{254} absorbance

Figure 9: Raw and Treated Water True Color

Membrane Performance Following MIEX® Pretreatment

Figure 10 shows the transmembrane pressure (TMP) vs the number of days of continual operation without a clean in place (CIP). A single module CMFS unit was run at two different fluxes (80L/hr/module and 100L/hr/module) alternatively on raw (untreated) water and water that had been pretreated by the MIEX® plant. This graph indicates two key findings. Firstly, the fouling rate is not increased by MIEX® pretreatment – if anything the rate of fouling actually appears to be slightly lower after pretreatment. Secondly, there is no evidence of irreversible fouling, as the module cleaned back to approximately the same initial TMP level.

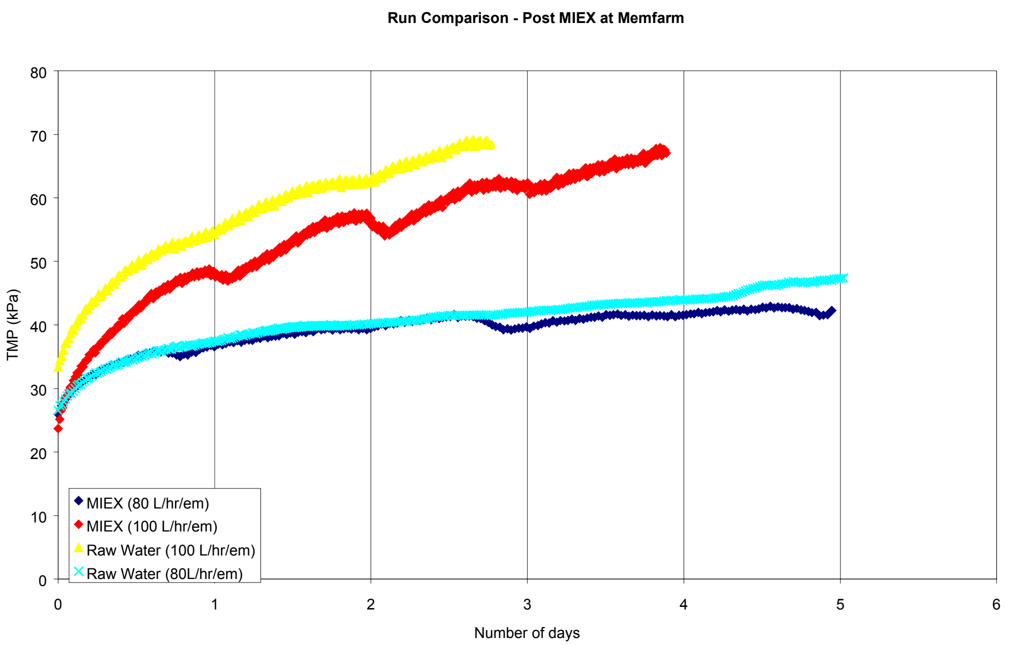


Figure 10: Comparative Run Data.

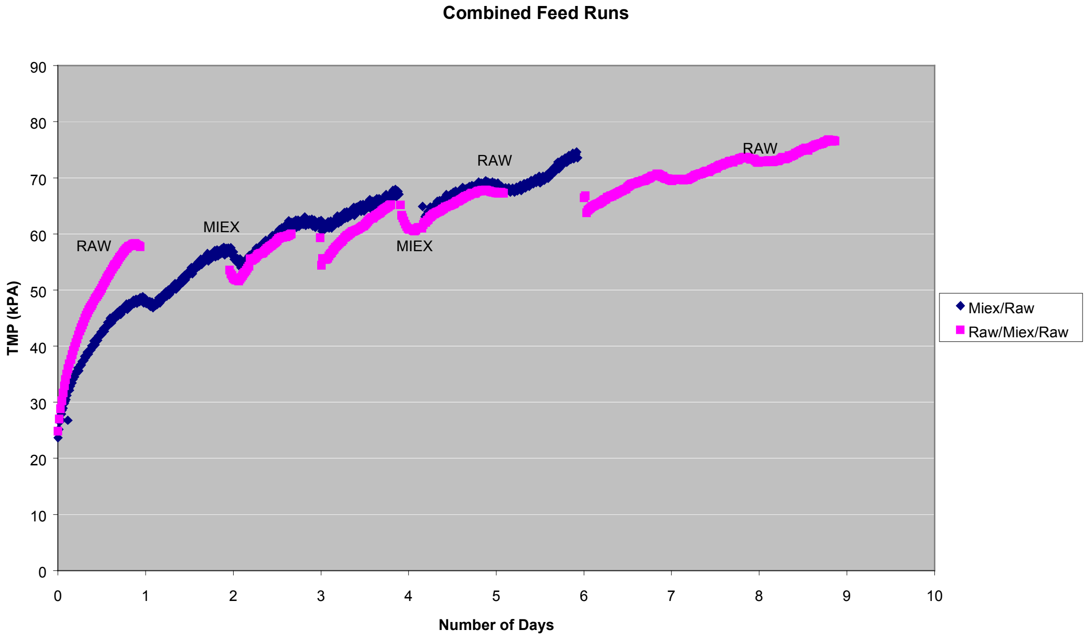


Figure 11: Combined Feed Run Data.

The CMFS run data depicted in Figure 11 was collected by switching between feeding raw water and MIEX® pretreated water to the CMFS unit between CIPs. CIPs are indicted by breaks in the curves. The objective here was to identify any change in the gradient of the performance curve when switching between feeds. Except for the first portion of the Raw/MIEX/Raw curve (a period of high turbidity feed water after heavy rain), the performance curves appear to follow the same gradient regardless of feed. It is also worth noting that the somewhat more oscillatory nature of the MIEX® pretreated feed-water curves is a result of temperature cycling over 24 hours (the break tank for MIEX® feed water was smaller than that for raw water and was in the direct sunlight during the day). As temperature increases, water viscosity decreases, bringing about an increase in flux at the same TMP, or a decrease in TMP at the same flux.

Trial Conclusions

An analysis of membrane performance data indicated that there is no detrimental effect due to MIEX® resin carryover. Fouling rates did not increase as a result of MIEX® pretreatment, and appear to have been reduced. Also, there is no evidence of any irreversible membrane fouling due to MIEX® resin carryover, where the polypropylene filter submodule cleaned back to the original resistance level. The resin performance results suggest that the resin is performing its designated task well, considering the difficult nature of the raw water source.

Full Scale Implementation in Australia

A trial was conducted by the South Australian Water Corporation between December 1999 and May 2000 using MIEX® for raw water pretreatment prior to both US Filter and Zenon pilot plants[6]. This trial was conducted to evaluate treatment technologies for a new 2.5 million liters per day water treatment plant at Mt Pleasant, South Australia. Water taken directly from the River Murray was treated by the MIEX® pilot plant using approximately 6mL/L MIEX® at a contact time of 18 to 36 minutes. These operating conditions achieved removals of 80% color, 60% UV_{254} absorbance and 50% DOC. The average raw water DOC and color were 6.5mg/l and 15 Pt Co Units respectively. Increasing the resin dose to 9mL/L later in the trial resulted in 70–75% removal of UV_{254} absorbance.

A major objective of this trial was to evaluate this treatment regime for future retrofitting into some of SA Water's treatment plants in the city of Adelaide. Following this trial, SA Water awarded a contract to build a full-scale MIEX®/microfiltration plant at Mt Pleasant, SA and this is due to be commissioned in June 2001.

Application in North America

The introduction of Stage 1 of the DBPR and the Interim Enhanced Surface Water Treatment Rule (IESWTR) will mean many small systems will require plant upgrades to meet both DBP and microbial standards. In some cases existing plants can be upgraded but in many cases complete replacement will be necessary.

Where enhanced coagulation cannot achieve the required NOM removal, Nanofiltration is currently considered as one of the technology options that can meet the tighter DBP standards. When softening is not necessary, the MIEX®/low pressure membrane treatment regime has benefits over NF because NF also removes alkalinity and other dissolved salts resulting in a large saline waste stream requiring disposal. For low alkalinity waters the NF treated water also needs to be restablized to reduce corrosivity. Up to 15-20% of the NF feed water is wasted while MIEX® regeneration waste is only around 0.015-0.08% of the raw water flow.

A comparison of operating costs for MIEX® and low pressure membranes versus NF and RO is shown in Table 1:

Table 1: Comparative Capital and Operating Costs for MIEX®/MF versus NF and RO

Technology	Capital Costs, $/gpd	Operating Costs - $/MG
MIEX®	0.17*	150
Microfiltration	0.50	90
	0.67	240
Pretreatment	**	**
NF/RO	0.70	130

*based on Wanneroo 60 MGD plant cost of US$10M
**Depends upon source water quality

Conclusions

Tightening EPA DBP and microbial standards are forcing many utilities to investigate new treatment technologies where existing conventional treatment process are no longer viable. Where water supplies have NOM present that is difficult to remove using coagulation, pretreatment with MIEX® resin followed by microfiltration or ultrafiltration can be a cost effective alternative to high pressure membrane systems such as nanofiltration or reverse osmosis.

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