World's First Magnetic Ion Exchange (MIEX®)[1] Water Treatment Plant to be Installed in Western Australia

Keith Cadee, Bernie O'Leary, Paul Smith
Water Corporation of Western Australia, Perth, Australia

Marin Slunjski , Michael Bourke
Orica Watercare, Melbourne, Australia

INTRODUCTION

Since the mid-1980s, the Water Corporation of Western Australia (WCWA) has been investigating technologies to prevent an intermittent 'swampy' odor occurring in the city of Perth's treated ground-waters (O'Leary and Herbert, 1998). Groundwater contributes around 50% of the water supply for Perth, which has a population of approximately 1.3 million. The Wanneroo Groundwater Treatment Plant (GWTP) is Perth's largest, with a flow rate of 59 MGD (225 ML/d), and treats 20% of the city's water supply. The groundwater supplies are typically treated using aeration, coagulation, sedimentation and filtration. The compound responsible for the odor, identified as dimethyl trisulphide (DMTS), is most likely a product of bacterial activity in the distribution system.

Trials of various technologies have been performed at the Wanneroo GWTP to determine how to enhance the existing treatment regime to prevent the formation of odors in the distribution system. In the last 12 months, enhanced coagulation has been introduced at Wanneroo GWTP, which has reduced but not eliminated downstream DMTS formation. Technologies trialed have included granular activated carbon (GAC), ozone/biological GAC (O_3/BGAC), enhanced coagulation, and microfiltration and since 1997, a process based on a magnetised ion exchange resin, the MIEX® resin. The treatment objective for these technologies was to reduce the current treated water DOC and non-sulphide-reduced-sulphur (NSRS) levels entering the distribution system. Elevated levels of DOC contribute to biofilm formation in the distribution system, which, in addition to NSRS, is strongly aligned to DMTS formation (Franzmann et al, 1999).

In this paper, piloting and selection of the process based on the MIEX® resin for improvement of the Wanneroo GWTP treatment process is described. The MIEX® Plant concept design is completed, and the plant commissioning is planned for mid 2001.

---

[1] MIEX® is a trademark of Orica Limited.

DESCRIPTION OF THE RESIN PROCESS

This truly continuous ion exchange process employs a newly developed, magnetic ion exchange resin. The MIEX® resin was specially designed for the removal of DOC from drinking water supplies. The negatively charged DOC is removed from water by exchanging with a chloride ion on active sites on the resin surface (Fig 1).

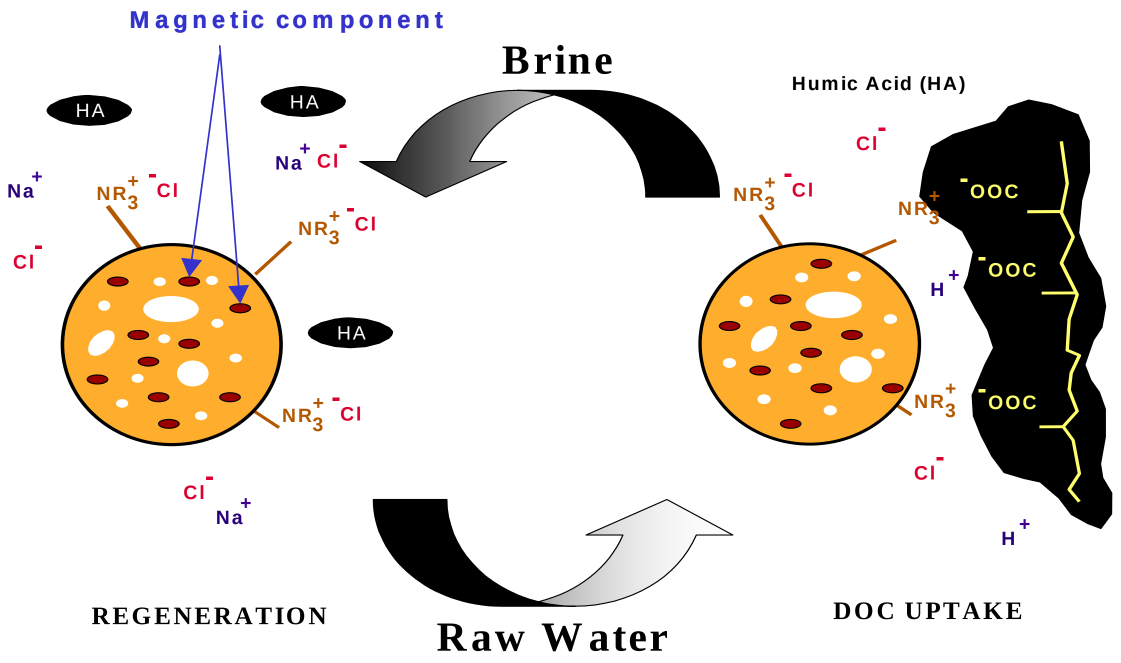

Figure 1: **DOC Removal Chemistry for MIEX® Resin**

Unlike conventional ion exchange processes the MIEX® resin has been developed to enable removal of DOC to occur in a stirred contactor, much like a flash mixer in a conventional water treatment plant. The resin beads are much smaller than conventional resin beads at around 180 µm (80 mesh), to allow rapid DOC adsorption kinetics in the contact vessel. Under mixing conditions, the resin beads are uniformly dispersed in water to maximise the kinetics of DOC exchange. This reduces the resin inventory in contact with water to only 2-12% of that normally associated with conventional ion exchange processes.

The resin moves through the plant with water. A magnetic component is built into the resin particle structure so that when mixing is removed, the fine resin beads rapidly agglomerate into larger, fast settling particles. The settling rate of these magnetically agglomerated beads is two orders of magnitude greater than predicted by Stokes free settling of the individual resin beads (Doblin, 2000). This 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 (4 gpm/ft^2 or 10m^{3}m^{-2}h^{-1}).

Most of the resin recovered from the settler is recycled back to the contactor. A small portion of the recovered resin is continuously diverted to a resin regeneration system. This is usually 5 to 10 % of the total settler underflow. In order to maintain DOC exchange capacity in the system, the resin removed for regeneration is replaced by the feed of fresh resin. Resin lost due to carryover from the settler is also made-up by the feed of fresh resin (Figure 2).

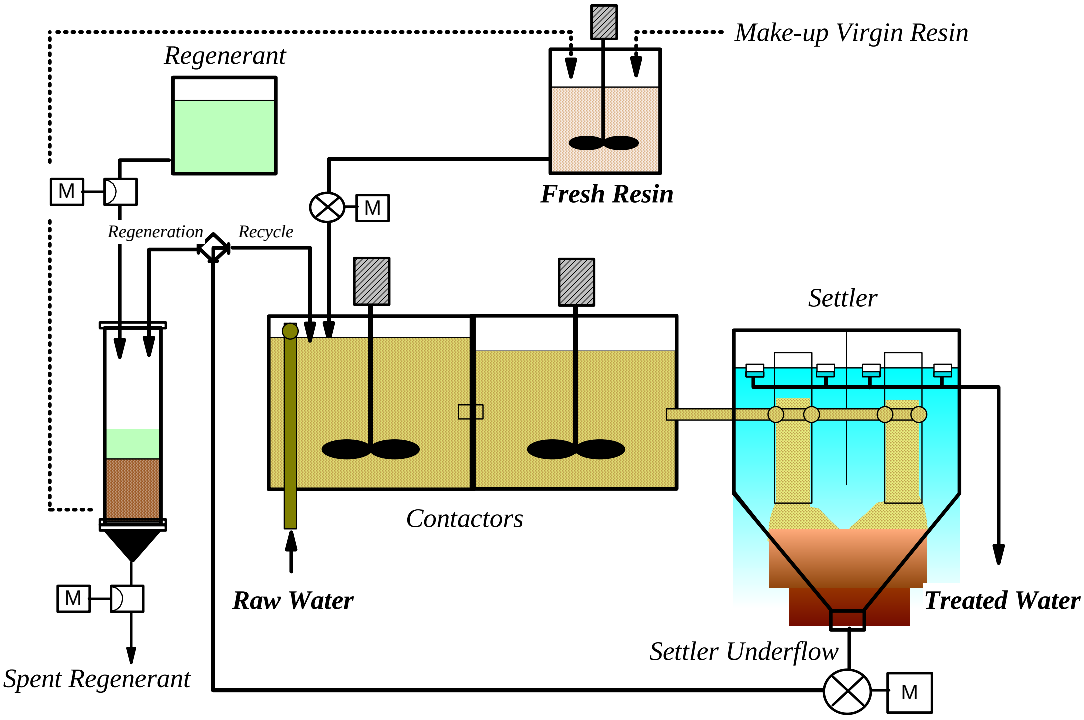

Figure 2: **Flow Diagram of Wanneroo MIEX® Resin Pilot Plant**

The regeneration system is additional to the main water treatment system (Figure 2). It is operated batch-wise, ie. when a pre-determined amount of the loaded resin is accumulated. Resin loaded with DOC is treated with a concentrated (10%w/w) brine (NaCl) solution. This reverses the exchange reaction, ie. the resin substitutes DOC for chloride ions from brine, and releases it into the brine solution. The two main parameters that control efficiency of the regeneration are chloride concentration (70 g/l) and contact time (30 min). Occasionally, small additions of caustic soda or acid to the brine may be required, depending on raw water characteristics, to enhance the regeneration process.

Following regeneration, the resin is transferred to the fresh resin tank and slowly fed back into the process (Figure 2).

In this process, the product water is of consistent quality because the overall ion exchange capacity in the contactor is continuously maintained. The DOC leakage is controlled at a pre-determined level. Furthermore, because of the resin's high selectivity for DOC, under the usual operating conditions no other anions are exchanged except for sulphate.

PILOT TRIALS

A 0.26 MGD (1 MLD) pilot plant was constructed in order to trial this process at the Wanneroo GWTP (Figure 3). A pilot plant of this large size was chosen so that engineering design parameters for a full-scale plant could be determined during the trial. The objectives of the trial were as follows (Bourke et al, 1999):

- to achieve 60% removal of raw water NSRS and DOC after combined MIEX® resin and alum treatment,
- to develop design parameters for a full scale plant, and
- to determine operating costs for a full scale 59 MGD (225 MLD) plant at Wanneroo.

Figure 3: **0.26 MGD (1 MLD) MIEX® Resin Pilot Plant at Wanneroo, WA, Australia**

Three trials each of around 6 week's duration were conducted between July 1997 and July 1998. During the first trial the operating conditions and regeneration process were optimised to determine if the treated water quality objectives could be met.

Based on the findings from the first trial, the operating conditions in trial 2 were kept constant at a contactor resin concentration of 0.8%v/v (30 mL settled resin per gal, or 8mL/L), a contact time of 30 minutes and a settler rise rate of 2.9 gpm/ft^2 (7 m^{3}m^{-2}h^{-1}). The primary objectives of this trial were to determine treated water DOC and NSRS removal rates at the stable operating conditions and to measure resin carryover from the settler to get an indication of process operating costs. Secondary objectives were to measure DOC, NSRS and THMFP reductions using combined MIEX® resin/alum coagulation treatment.

A third trial was conducted during May/June 1998 to measure resin carryover at settler rise rates of 4 to 6 gpm/ft^2 (10 to 15 $m^3m^{-2}h^{-1}$), and to determine the resin performance with regenerant re-use. In the second part of this trial, the process performance was measured for treatment of clarified water after alum coagulation.

Raw water is supplied to the Wanneroo GWTP by 49 wells. The raw water quality received at the plant at any time is a composite of many different wells, each with substantially different water quality characteristics. As a result, the raw water quality is very variable - DOC 7-15 mg/L, iron 1-4 mg/L, and sulphides 0.4-0.9 mg/L.

Water received at the plant first undergoes aeration to oxidise dissolved iron prior to conventional coagulation, sedimentation and filtration. For Trials 1 and 2, and first part of Trial 3, water was fed to the pilot plant after undergoing aeration (Fig 4). In the second part of Trial 3, water after sedimentation was treated in the pilot plant.

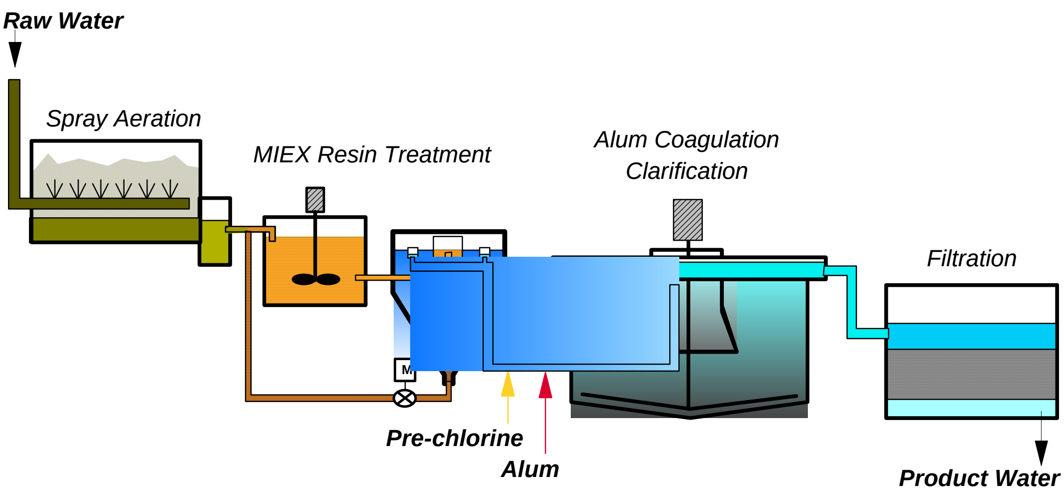

Figure 4: **Wanneroo GWTP Process, including MIEX® Plant**

The results from Trial 2 showed that greater than 75% DOC and 90% NSRS removal could be consistently achieved when the resin process was used in conjunction with conventional or enhanced coagulation. The THM formation potential of the water was also reduced by 85%. These removal rates were significantly greater than those achieved with enhanced coagulation alone (Fig 5).

When raw water was pre-treated with MIEX® resin, it was possible to reduce downstream alum doses by up to 70% while still meeting the treated water quality objectives. This treatment regime would significantly reduce the volume of chemical sludge currently generated at the Wanneroo GWTP.

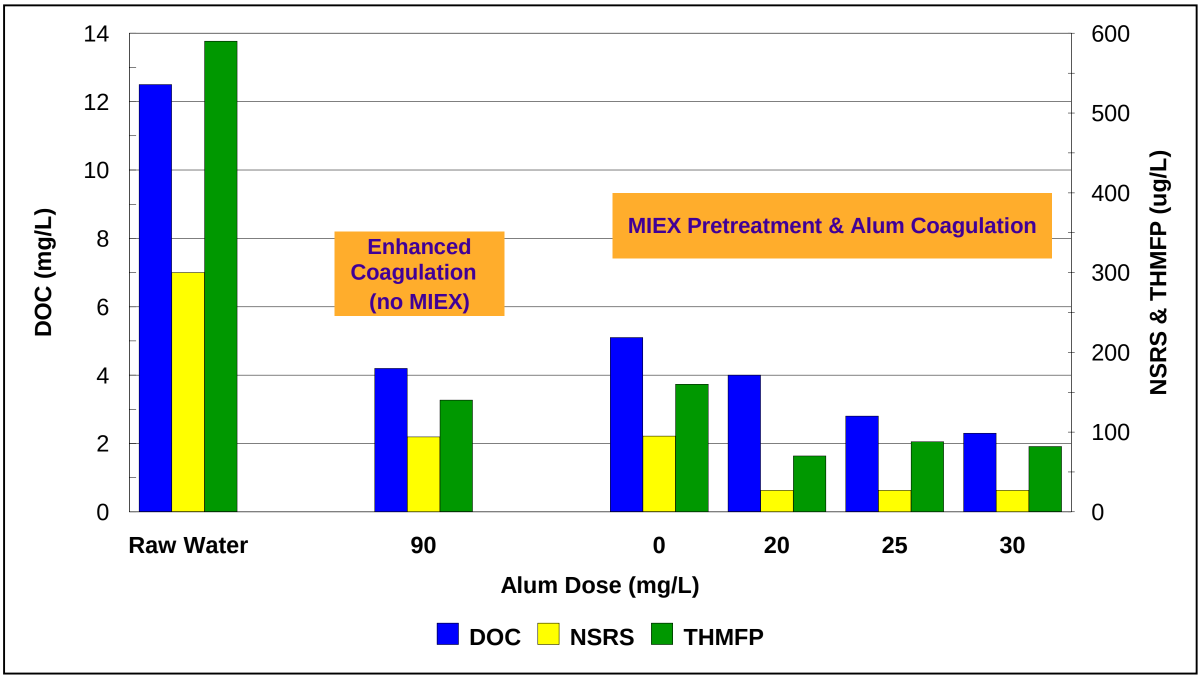

Figure 5: **Typical Treated Water Quality after Enhanced Coagulation, MIEX® Resin and Combined Treatment**

The results from Trial 3 showed that there was little difference in treated water DOC and NSRS levels achieved, regardless of whether the resin process was used before or after coagulation. The main benefits identified in using MIEX® prior to coagulation is that the same water quality is achieved at a significantly lower alum dose and that regeneration is more efficient due to the absence of sulphates contributed by alum. Some caustic and acid regenerations are expected with the pre-clarifier application due to raw water iron levels.

CHARACTERISATION OF DOC REMOVED

The DOC removals achieved for the various treatment regimes (Figure 5) show that 3-3.5 mg/L of DOC remains after enhanced coagulation (pre-chlorine 4.8 mg/L, alum dose 90 mg/L, polymer dose 0.70 mg/L, pH 6.1) of Wanneroo raw water. In comparison, after MIEX® resin pre-treatment, it was possible to reduce the treated water DOC to below 2 mg/L with low alum doses.

These results suggested that the MIEX® resin and coagulation are preferentially removing different DOC fractions, thereby providing greater overall DOC removal when used together. Size exclusion chromatography (SEC) technique was used to generate UV absorbance (254 nm) versus molecular weight profiles for raw and treated waters after individual (Figure 6) and combined treatments (Figure 7).

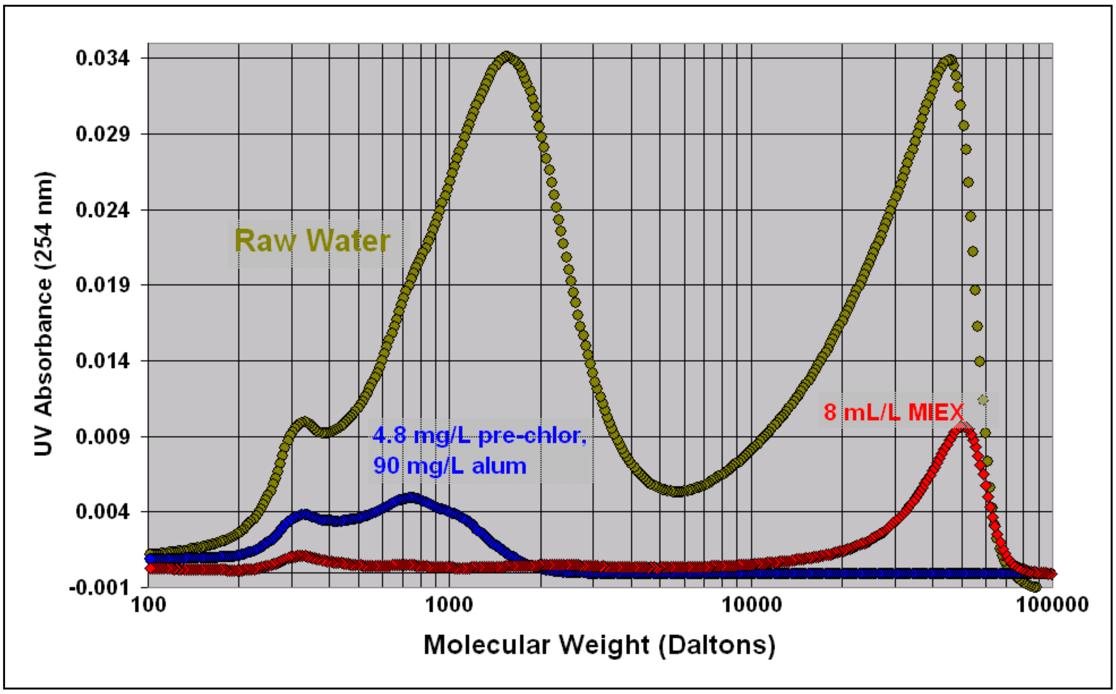

Figure 6: **SEC Profiles - Raw, Enhanced Coagulated and MIEX® Treated Water**

The SEC results (Figure 6) showed that the MIEX® resin at a concentration of 0.8%v/v preferentially removed lower molecular weight DOC from Wanneroo ground water (Slunjski et al, 2000). In contrast, alum treatment even at high alum doses (90 mg/L alum) and modified pH (6.1), ie. "enhanced coagulation", failed to remove a significant amount of low molecular weight DOC. At the time of the tests outlined in Fig 6, the raw water contained 9.5 mg/L DOC. Treated water contained 1.8 mg/L DOC after MIEX® resin and 3.1 mg/L DOC after enhanced coagulation treatment.

SEC profiles for combined treatments indicated almost complete removal of UV absorbing DOC (Figure 7). These results were further confirmed by the corresponding DOC results:

- Enhanced alum coagulation treatment (90 mg/L alum, pH 6.41) followed by MIEX® jar test (0.4% v/v resin, 30 min) reduced DOC from 9.5 mg/L to 1.5 mg/L, while

- MIEX® jar test (0.8% v/v resin, 30 min) followed by alum jar test (30 mg/L) reduced DOC from 9.5 mg/L to 1.7 mg/L DOC.

These results show the synergies that can be achieved by combining the MIEX® resin treatment with the existing treatment process at Wanneroo GWTP, leading to an improvement in water quality.

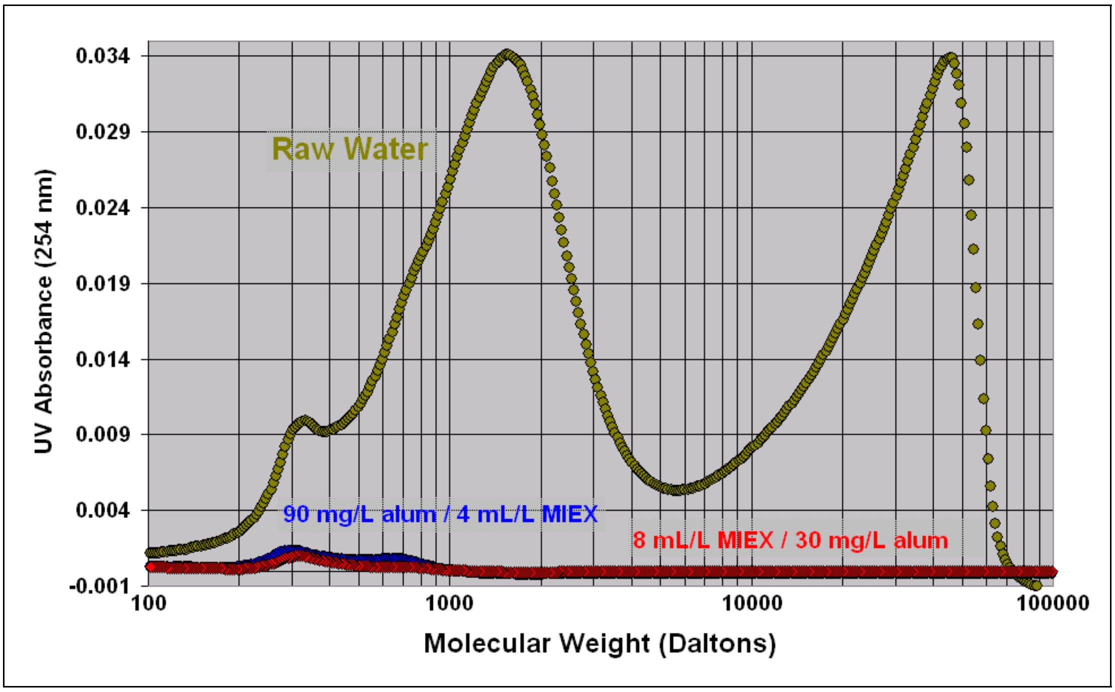

Figure 7: **SEC Profiles for Combined Treatments**

The results also show that the selection of optimum treatment sequence can only be made based on the overall efficiencies of process combinations with respect to chemical consumption and waste production, and not on the final water quality (Slunjski et al, 2000).

SELECTION AND FULL-SCALE IMPLEMENTATION OF THE RESIN PROCESS AT WANNEROO GWTP

Since the raw water at Wanneroo contained substantial concentrations of DOC it was considered important to have a two-stage reduction process.

A target of 1.5 mg/L DOC in final clear water was set based on an estimate that this will enable final chlorination, at current or even at a reduced level, to penetrate widely over the metropolitan area with minimal decay. This has been shown to inhibit biofilm formation, which in turn minimised the propensity to form DMTS. Hence, all performance and cost comparisons were based on achieving the target 1.5 mg/L DOC in final clear water.

The MIEX® resin process was selected over GAC and O_3/BGAC polishing based on more consistent achievement of target DOC concentrations, combined with lower capital and operating costs.

The use of GAC as a total replacement for conventional filter media was seen as potentially compromising the final product water quality, due to different media and backwashing requirements for conventional and organics reduction processes. Also, pilot plant trials have determined that the carbon would need to be replaced every 2 months to achieve similar target DOC levels.

Pilot trials with an ozone/BGAC process, replacing the existing sand/anthracite media in single stage filters, demonstrated that a target DOC level of 1.5 mg/L could only be achieved with a carbon life of no more than 2 months. It is recognised that this ozone based treatment is primarily targeted at a longer term reduction in biologically degradable organic carbon (BDOC), but it was considered that reduction in DOC to the target levels was the more important parameter for DMTS reduction.

Costs were also estimated for ozone/BGAC in GAC contactors downstream of the existing filters. An estimated carbon life of 4 months was assumed, due to two-stage filtration being used. These costs are compared in the Table 1.

Table 1: **Cost Comparisons for DOC Removal Processes for Wanneroo GWTP (for approximately 40-50% DOC Removal).**

OPTIONS	Capital Cost US$ M***	Operating Cost US Cents / 1000 gal	NPV** US$ M
MIEX® Resin Treatment	9.1	24	31.5
O_3/BGAC* (existing filters) Assume 2 months carbon life	8.5	76	99.3
O_3/BGAC (dual filters) Assume 4 months carbon life	12.1	38	49.7
GAC in existing filters Assume 2 months carbon life	3.0	73	95.1

* it is assumed the existing sand/anthracite filters can be converted to carbon.
** 30 year Net Present Value with 8% Weighed Average Cost of Capital (WACC)
*** estimates in Australian Dollars were converted using exchange rate of 1 AU$ = 0.60561 US$

The MIEX® resin treatment, in combination with the current treatment process was shown to be capable of achieving the DOC target. Furthermore, the comparison of cost estimates (Table 1) indicated that capital costs for the resin process are about 75% of O_3/BGAC costs (when dual filters was assumed). Also, operating costs are estimated to be only 32% of O_3/BGAC costs with existing filters and 63% with dual filters.

The MIEX® resin operating costs take into account a reduction in alum dose from 75 to 25 mg/L, and waste regenerant disposal (app. 0.015 % v/v water treated), but do not include further cost reductions due to a lower lime dose and a 65-75% reduction in chemical sludge production.

Although the MIEX® resin process can be used to treat clarified water, it was decided to place it between aeration and alum coagulation (Figure 4). In this way a substantial reduction in DOC will be achieved before alum addition. This arrangement also maintains flexibility in alum dosing, from 30% of normal alum dose up to enhanced coagulation dose. This will allow implementing different treatment strategies as the impact of varying levels of DOC in the clear water on DMTS minimisation becomes further understood.

Replacing the current sand filtration with low cost biological sand / anthracite filtration is currently being investigated to determine if a further reduction in BDOC is beneficial.

The concept design of a 59 MGD (225 MLD) MIEX® plant has been completed. The plant will be built to contain three 20 MGD (75 MLD) process trains (Figure 8). The plant commissioning is planned for mid 2001.

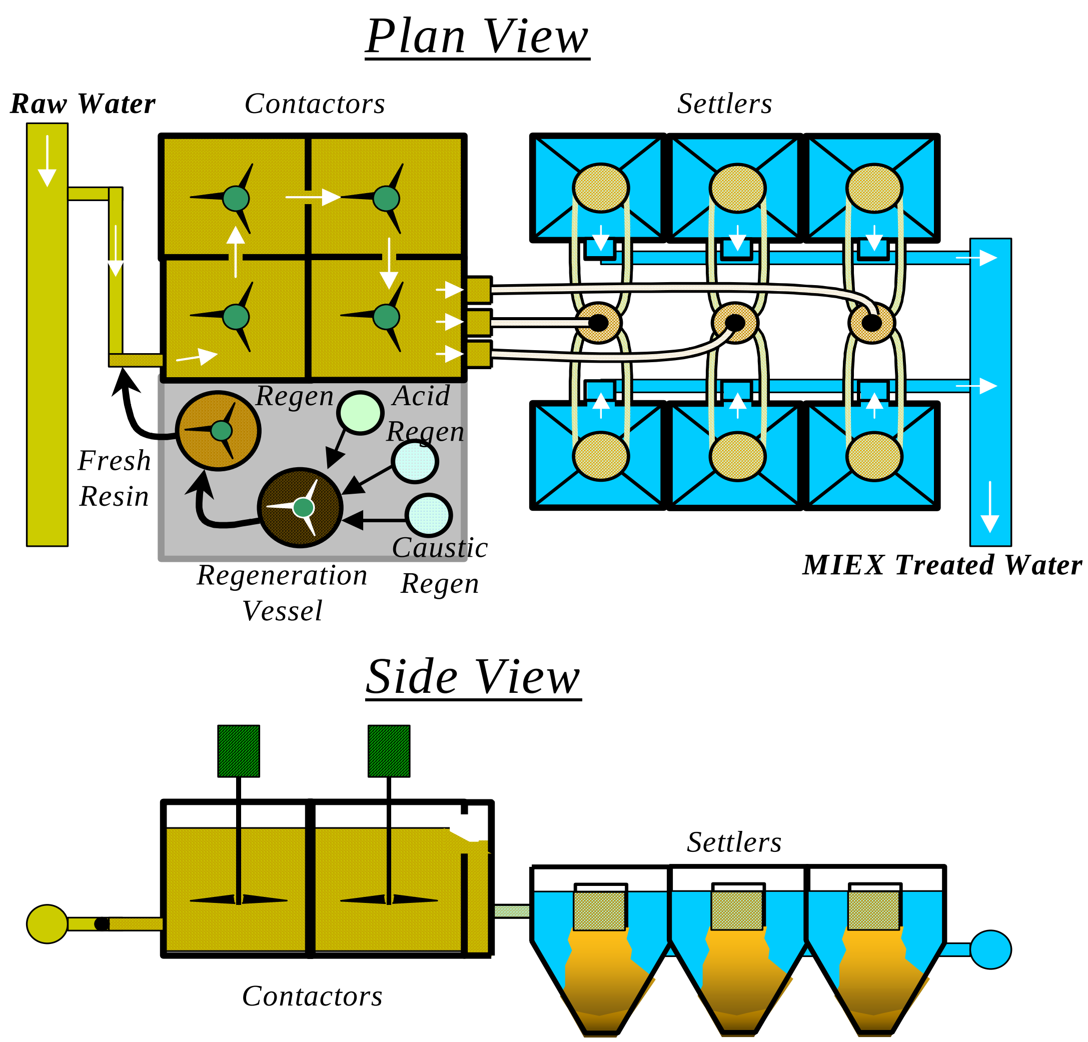

Figure 8: **One Process Train of the 59 MGD (225 MLD) MIEX® Plant at Wanneroo GWTP, WA, Australia**

CONCLUSIONS

Following extensive pilot studies involving alternative technologies, a treatment regime based on the MIEX® resin has been selected to provide the necessary improvement in water quality at the Wanneroo GWTP, Perth, Western Australia.

A combination of MIEX® resin and alum coagulation treatment was shown to be an efficient and cost effective solution capable of reducing the DOC level from 10-15 mg/L in the raw water down to 1.5 mg/L in the clear water. This DOC level is considered necessary to alleviate the DMTS odor problem in the distribution system.

The 59 MGD (225 MLD) MIEX® plant is currently in the design stage, with commissioning planned for mid 2001.

REFERENCES

O'Leary B, Herbert N, 1998
"Development of Water Treatment Processes for Perth's Future Groundwater Schemes", in Proceedings 11th IWSA-ASPAC Regional Conference: "Integrating the Urban Water Cycle", 1-5 Nov. 1998 Sydney, Australia, pp.465-472

Franzmann P.D, Heitz A, Zappia L.R, Wajon J.E, Xanthis K, 1999
"The Formation of "Swampy Odor" (Malodorous Dimethyl Oligosulfides) in Treated Groundwater: The Role of Biofilms and Potential Precursors", a consultancy report to the Water Corporation.

Bourke M, Slunjski M, O'Leary B, Smith P, 1999
"Scale-Up of the MIEX® DOC Process For Full Scale Water Treatment Plants", in Proceedings AWWA 18th Federal Convention, 11-14 Apr 1999 Adelaide, Australia

Doblin C, 2000
"Preliminary Settling Tests of MIEX® Resin Beads", an internal CSIRO-Orica report

Slunjski M, Bourke M, O'Leary B, 2000
"MIEX® DOC Process for Removal of Humics in Water Treatment", Symposium on Humic Substances – Science and Commercial Applications, IHSS – Australian Branch, Dept of Chemistry, Monash University, Melbourne, Australia, pp.22-27