MIEX® RESIN WATER TREATMENT PROCESS

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Abstract
The MIEX®[1] Resin process was developed in Australia for the removal of natural organic material in water treatment. This novel, truly continuous ion exchange process, is based on the MIEX® resin – a micro size, macroporous, strong base, magnetic ion exchange resin. The resin was specially developed for this application and optimised for reversible removal of negatively charged organic ions.

The MIEX® resin process uses mixed tanks for contacting resin with water. A very small amount of resin (5-10 mL settled resin per litre water) is used to exchange organics from water during 15-30 min detention time in a continuous, stirred tank reactor. After that, the resin is separated and treated water removed from the process for further treatment in a downstream settling unit. The gravity settling based resin separation 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 rate in the settler. Settled resin accumulates on the settler bottom and is pumped back to the contactor as concentrated slurry. Small amount of recycled resin is continuously removed for regeneration and replaced with regenerated resin.

This general concept of the MIEX® resin process is explained in detail in this paper and supported with results from a number of evaluation trials conducted in Australia.

Introduction

Sources of colour in ground water can include metallic ions (iron and manganese), and dissolved natural organic material (NOM, humic and fulvic acids). Conventional processes used for colour removal in water treatment include oxidation and precipitation of metallic ions and coagulation, flocculation, and filtration of NOM.

The removal of dissolved organic material (or carbon – DOC) from drinking water sources has become a major concern since trihalomethanes were found in chlorinated drinking water in 1974. In addition, reducing DOC reduces chlorine demand and can help prevent taste and odour problems in distribution.

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[1] MIEX is a registered trademark of Orica Australia.

The anion exchange process is an attractive method for removing DOC because the majority of these compounds are acidic (ionic). Conventional ion exchange systems have been and still are successfully used for the colour removal in water treatment (Hongve '99; Odegaard '99), however for relatively small size waterworks (1–60MLD). Scaling up of the conventional ion exchange processes to several hundreds of ML/day would require complex and costly infrastructure and substantial amounts of resin.

In response to these shortcomings of conventional approaches a new process was developed in Australia and has been extensively trialed over several years. This process is based on a new, specially formulated and patented MIEX® resin. Special features of this resin enabled it to be used in infrastructure that closely resembles conventional water treatment plants and is very different to ion exchange columns.

Removal of DOC with MIEX® Resin

The MIEX® resin has strong base functionality hence is capable of exchanging weak organic acid ions at the neutral pH of most raw waters. High selectivity of strong base resins for highly charged organic ions enables these ions to be effectively removed at very low inlet concentrations, typically <15 mg/L DOC. The exchange of DOC ions proceeds in accordance to the diagram in figure 1.

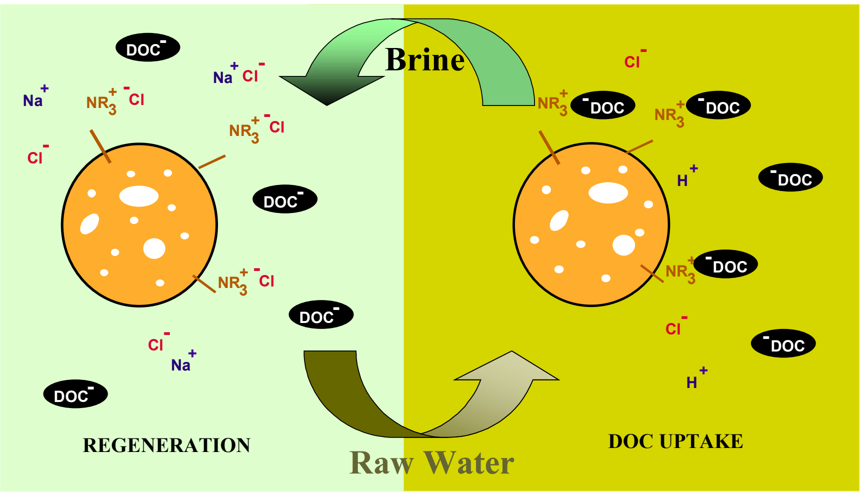


Figure 1:
DOC Exchange

The MIEX® Resin

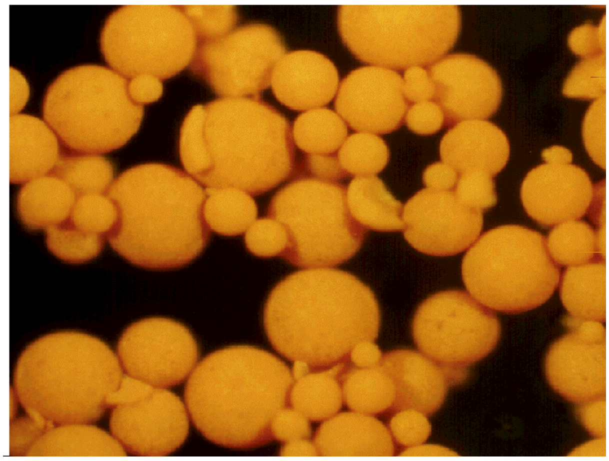


Figure 2:
MIEX® Resin

The MIEX® resin was specially developed and optimised for the removal of DOC in municipal water treatment. In addition to the strong base activity, this resin has a macroporous structure made from a moderately cross-linked acrylic skeleton. Because of that, the resin is highly resistant to physical attrition and organic fouling.

It also has a very small particle size – mean particle diameter is only 180μm. With a specific surface area comparable to other conventional macroporous resins, this resin has a lot more external bead surface. This benefits the DOC exchange kinetics (less controlled by the particle diffusion) and the resistance to fouling (less DOC exchanged into the particles, shorter diffusion paths with smaller beads).

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 agglomerating into large, heavy agglomerates formed under the right hydraulic conditions. This very special feature is where the MIEX® name is coming from – **M**agnetic **I**on **EX**change and it enables this resin to be applied to water treatment in a quite unusual way.

The MIEX® Resin Process

The process for DOC removal based on the MIEX® resin includes resin contacting with water, resin separation and recycle, and resin regeneration. The first two processes are integral to the main water treatment plant, while the resin regeneration is conducted in a dedicated system.

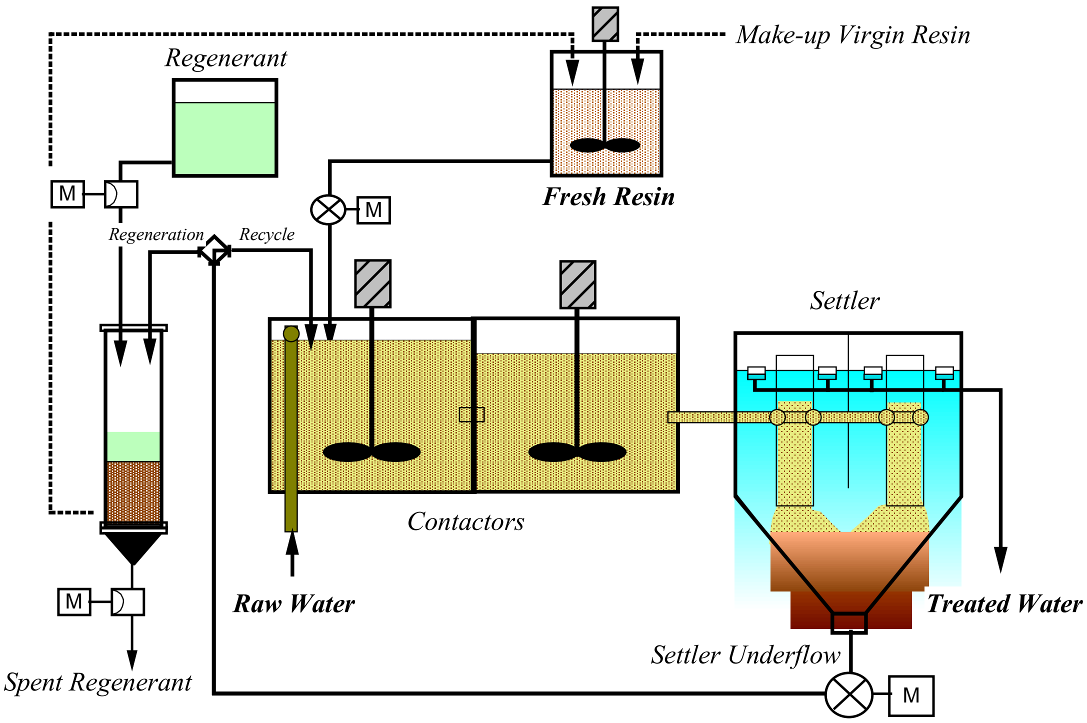
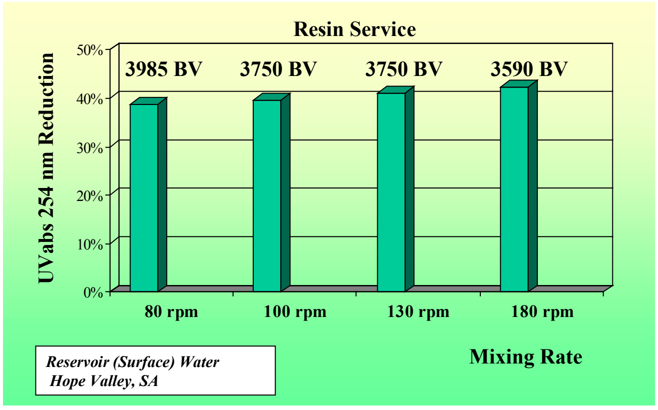


Figure 3: **Flow Diagram of Wanneroo MIEX® Resin Pilot Plant**

Mixed contacting vessels provide 10-30 min detention time during which the DOC is exchanged onto the resin. The vessels are designed to meet the requirements of solid-

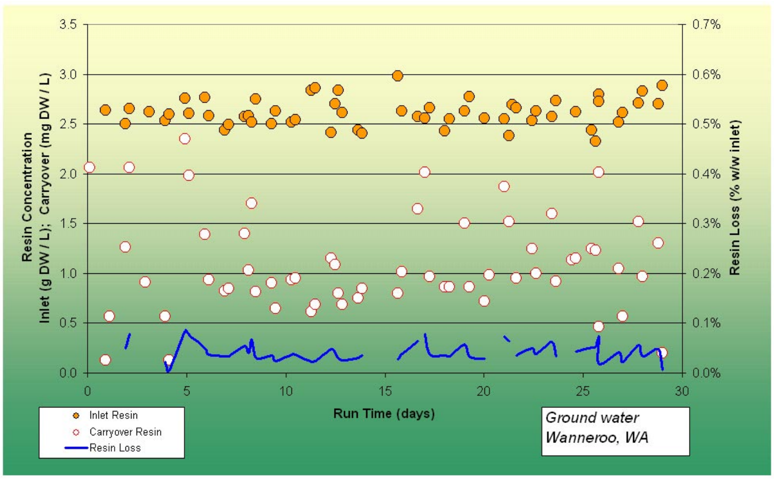
liquid agitation in an agitated vessel. Usually, 2-3 smaller contactors in series are used instead of one larger one in order to minimise short-circuiting.
The agitation is achieved with low shear impellers operated at a low speed (tip speed is <5 m/sec). The resin is dosed to the contactor at a very low concentration (0.5-1.0% v/v based on settled resin volume). Magnetic attraction of individual resin beads is limited to very short distances consequently low energy inputs are required for maintaining the resin in suspension.



Full dispersion of individual resin beads is not required as demonstrated by very low improvements in the DOC removal as a function of the level of mixing shown in fig 4.

Figure 4:
Effect of Mixing Rate

The resin-water suspension flows by gravity to the resin separation stage. The inlet is designed similar to a flocculating feedwell for maximum dissipation of inlet jet energy and for inter-particle collisions under gentle swirl conditions. This results in "magnetic" agglomeration of individual resin beads.



The agglomerates formed are capable of settling against high up-flow of water. The resulting resin separation efficiency exceeds 99.9%.

Figure 5:
Resin Carryover

In the settler, the resin is subjected to continuous "back-wash" conditions which prevents any turbidity accumulation in the system. Carryover of resin from this process actually contributes to the product water turbidity as shown in figure 5 (Nguyen et al. 1997).

Settled resin is thickened to 20-30% v/v (settled resin volume) and pumped back to the contacting vessel for another loading cycle. For this operation, hose and/or "open" impeller pumps are used to minimise resin attrition. Again, this is possible because of the very small resin size and additives built into its structure to increase elasticity of beads.

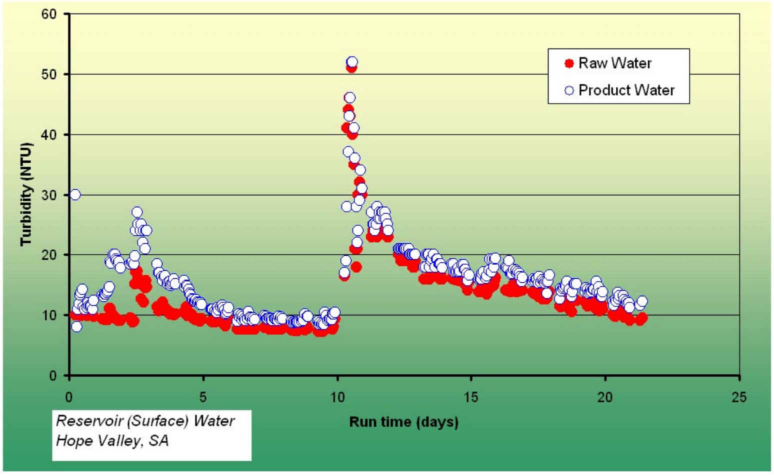


Figure 6:
Effect on Turbidity

From the recycle line, a small amount of used resin is continuously removed for regeneration and replaced with fresh, regenerated resin. The fresh resin feed pump can be feedback controlled to ensure the contactor concentration is maintained.

The used MIEX® resin is regenerated batch-wise, after a sufficient amount of resin is accumulated in the regeneration system. Usually, the regeneration frequency is 6-8 hours.

No resin backwashing is required at the start of the regeneration. This is despite no pre-treatment for solids removal being required by the MIEX® resin process.

The regenerant used is 100-120 g/L NaCl solution dosed at 360 g NaCl per litre of resin. The actual salt consumption of 90 g per L regenerated resin is achieved by re-using the regenerant a number of times.

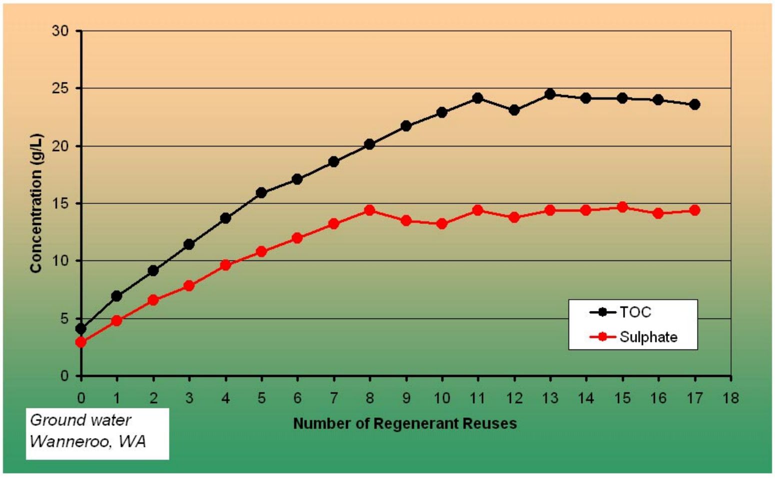


Figure 7:
Reused Regenerant Composition

Small additions of NaOH to the brine regenerant may also be beneficial for some waters, as well as periodical acid washes when it is required to remove metal precipitates from the resin.

Little (1 bed volume) or no rinsing is required due to the regenerated resin being fed back into the process at a very slow rate of 0.05-0.10 % v/v to the plant throughput. However, it is required to completely drain the resin bed before it is resuspended for transfer to the fresh resin tank at the end of the regeneration.

Water consumption for regeneration and waste generation is below 0.1% water treated.

Process Performance and Benefits
The MIEX® resin process is a truly continuous ion exchange process. It does not require any pre-treatment and produces water of a consistent quality as shown in figure 8 (Nguyen et al. 1997; Bourke et al. 1999).

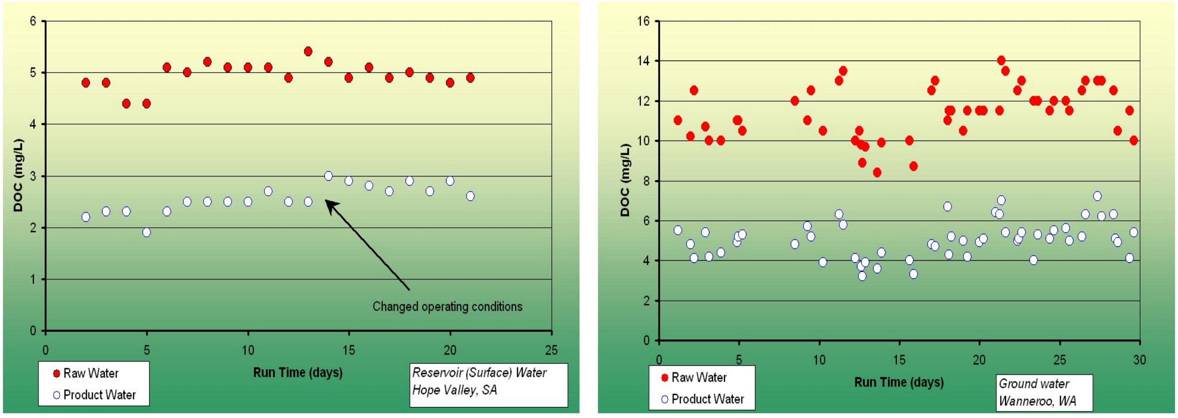


Figure 8: **MIEX® Resin Process DOC Removal**

The process can easily be combined with conventional flocculation/coagulation processes and membrane filtration processes. In combination with the alum treatment, an added benefit is the MIEX® resin preferential removal of the DOC fraction not removed by alum even at very high doses as demonstrated on the Wanneroo (Perth, Australia) water (Slunjski et al 2000).

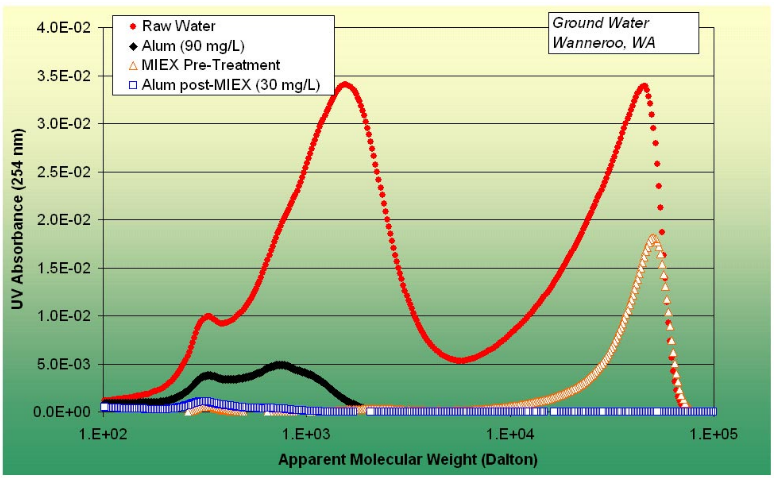


Figure 9:
Size Exclusion Chromatography Profiles

The process was also very effective in removing non-sulphide reduced sulphur (NSRS) compounds from Wanneroo ground water. These substances have been identified as a potential precursor for an undesirable water odour that occasionally develops in Perth's water distribution.

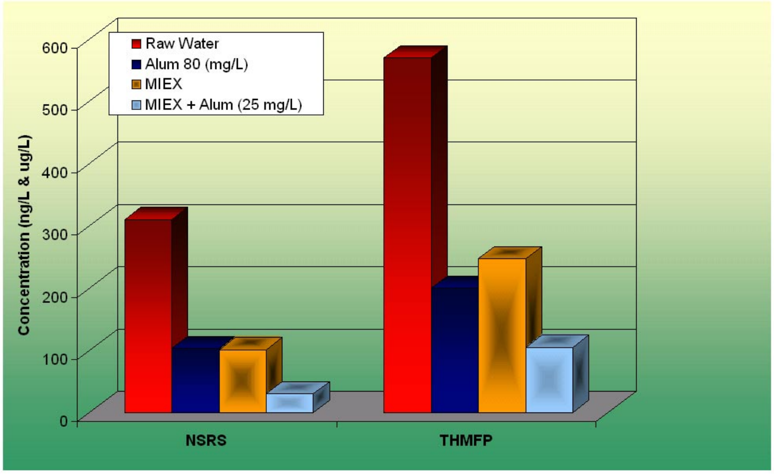


Figure 10: **NSRS and THMFP Results**

Very effective removal of DOC with the combined process also results with a superior trihalomethane formation potential (THMFP) reduction (Bourke et al. 1999).

The process design is compact and capital and operating costs are low. In table 1, comparative costs are given for DOC removal processes evaluated at the Wanneroo Ground Water Treatment Plant in Perth, Western Australia (Cadee et al. 2000).

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* (in existing filters) 2 months carbon life assumed	8.5	76	99.3
O_3/BGAC (dual filters) 4 months carbon life assumed	12.1	38	49.7
GAC in existing filters 2 months carbon life assumed	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 1 AU$ = 0.60561 US$ exchange rate

The MIEX® process capital cost is low not only because very simple, conventional equipment is used for the MIEX® plant, but also because the resin inventory is only 15-25% of that for a conventional ion exchange plant[2].

There is also no requirement for large capital outlays for periodical resin bed replacements. The MIEX® inventory is continuously re-newed with a small amount of make-up resin added to replace the resin lost due to the carryover. Hence, the resin replacement cost is factored into the operating cost (table 1).

Commercial Situation

This process was developed and extensively trialed in Australia since early '90s (Morran et al '96; Bursill et al '96; Nguyen et al '97; Bourke et al '99).

In the last two years commercialisation is in a full swing with resin manufacturing and two application plants under construction in Australia (Bourke '99b; Kilmore et al 2000).

In addition, the technology is starting to be evaluated outside of Australia (Burchardt et al 2000).

By far the largest of the projects under way is the 225 MLD MIEX® plant being built by the Water Corporation of Western Australia (WCWA). This project is being undertaken at the WCWA's Wanneroo Ground Water Treatment Plant which provides ~20% of Perth's water supply. Following extensive 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 (Cadee et al 2000). This project is well underway with plant expected to be operational in early 2001.

Recently, WCWA have appointed Black&Veatch, a major international designer and constructor, as the EPC contractor to complete detail design and construct the MIEX® plant at Wanneroo on a turnkey basis.

Conclusions

The MIEX® resin was specially developed and optimised for the DOC removal in water treatment. Unique resin properties discussed in this paper are the basis for the very unusual and very effective design of this novel ion exchange process.

Very good and consistent DOC removal performance observed during extensive pilot trials in Australia was the basis for its commercial application on a 225 MLD scale at the Wanneroo GWTP in Perth, Australia.

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[2] Standard operating conditions are assumed for the MIEX® process – resin concentration 8 mL/L, contact time 30 min, regeneration rate 10%, regeneration frequency 8 hours; Operating parameters assumed for a conventional plant were – EBCT 5 min, 20% regeneration redundancy.

Acknowledgements
The MIEX® resin was developed in collaboration by Orica Australia and CSIRO Molecular Science. Orica Australia and SA Water Corporation developed the MIEX® resin application process. Water Corporation of Western Australia significantly contributed the process development and scale-up. The results presented in this report are from joint studies conducted by all above mentioned organisations.

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