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Full Scale Magnetic Ion Exchange Process Tested by Historically High DOC Levels

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EXECUTIVE SUMMARY
The Aireys Inlet Water Treatment Plant (WTP) is located about 150 kilometres from Melbourne on the Great Ocean Road. The WTP utilises a conventional upflow sludge blanket clarification process. The raw water source for this plant is characterised by high DOC levels. Despite operating in an enhanced coagulation mode sufficient DOC removal was not able to be achieved. This resulted in high chlorine demand at the plant, quick chlorine decay, low chlorine residuals and in turn bacterial regrowth in the distribution system. In addition, the reaction of chlorine with DOC led to the formation of elevated concentrations of disinfection by-products.

Installation of a MIEX® Plant in December 2004 has resulted in the following performance improvements:-

- Increased DOC removal from 40-50% to 60-80%;
- Reduced THM levels by approximately 60% to levels below the requirements of the US EPA Disinfection By-Product Rule Stage 1;
- Improved the operational stability of the downstream conventional treatment process; and
- Improved customer satisfaction.

This has been achieved despite a significant deterioration in raw water quality and without a significant increase in operational costs.

INTRODUCTION
The Aireys Inlet Water Treatment Plant (WTP), located about 150 kilometres from Melbourne, is operated by Barwon Water and sources its raw water from the Painkalac Reservoir. The raw water contains high levels of colour and dissolved organic carbon (DOC). These factors combined with low alkalinity and variable turbidity make this water very difficult to treat.

A continuous magnetic ion exchange (MIEX®) plant was installed in December 2004 as raw water pre-treatment for the existing 2.85 megalitre per day (MLD) conventional plant. MIEX® pretreatment has significantly reduced treated water dissolved organic carbon (DOC) levels and disinfection by-product (DBP) formation, reduced treatment chemical consumption and improved WTP stability.

This paper outlines process performance over the period of MIEX® plant operation, which includes unprecedented raw water DOC levels caused by a significant rain event in February 2005.

MIEX® PROCESS OVERVIEW
The key component of the MIEX® process is the MIEX® Resin which has been designed specifically for the removal of DOC from drinking water. Negatively charged DOC is

removed by exchanging with a chloride ion on the resin surface (see Figure 1). This results in a reduction in the DOC level and a small increase in the treated water chloride level.

The resin beads are much smaller than conventional ion exchange beads, at around 180 µm (80 mesh). The small bead size provides a high surface area allowing rapid DOC attachment and requiring very low resin concentrations to achieve good DOC removal.

The name "MIEX®" is derived from the term 'Magnetic Ion Exchange', because the ion exchange resin beads contain a magnetized component within their structure which allows the beads to act as weak individual magnets. The magnetised component draws the resins beads together under settling conditions to form floc, allowing easy separation of the resin from the treated water.

Resin loaded with DOC is regenerated through a reversed ion exchange reaction, where the resin substitutes chloride ions for DOC. The DOC is then released from the resin into a concentrated brine (NaCl) solution.

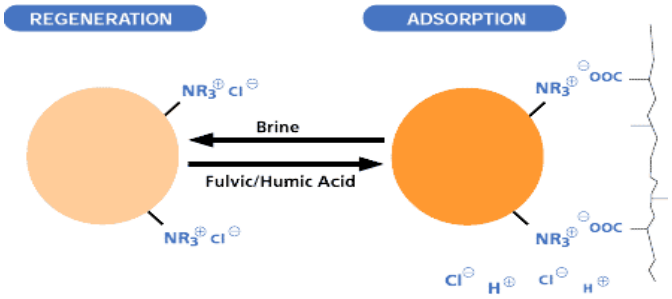


Figure 1: DOC Exchange

The resin is utilised in a continuous ion exchange process that includes resin contact with water, resin separation and recycle, and resin regeneration (see Figure 2).

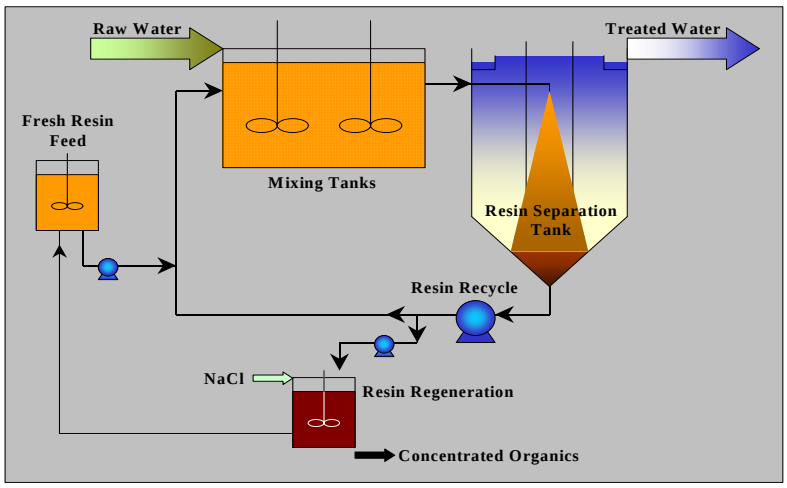


Figure 2: Flow Diagram for typical MIEX® Plant

A mixed contacting vessel provides 10-20 min detention time during which raw water DOC is exchanged onto the resin. The resin concentration in the contactor is very low (2.0-4.0% 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.

The resin-water suspension then 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.

Settled resin is thickened to 20-40% v/v (settled resin volume) and pumped back to the contacting vessel for another loading cycle.

From the recycle line, a small amount of used resin is continuously removed for regeneration and replaced with fresh, regenerated resin. 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.

Regeneration is achieved by pulling a brine solution through a bed of the MIEX® Resin and rising the resin with raw water. Minimal 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.

AIREYS INLET WATER SUPPLY SYSTEM OVERVIEW

Water Supply System

Raw water is harvested from a catchment of 3400Ha, consisting mainly of State Forrest and State Park, and stored in a 514 ML on-stream reservoir. As a result of sandy soil and vegetation types in the catchment, and a significant organic load that washed into the reservoir after the 1983 Ash Wednesday bush fires, the raw water contains high levels of colour and dissolved organic carbon (DOC).

Prior to MIEX® pretreatment the treatment process consisted of alum coagulation, upflow sludge blanket clarification, sand filtration and disinfection. To treat the raw water to acceptable turbidity and colour levels required the plant to be operated in enhanced coagulation mode. This requires high Aluminium Sulphate (Alum) doses and tight control of pH across the treatment process to manage Aluminium residuals.

Despite the high Alum doses, DOC removal was not very efficient with significant residual passing through the plant. This resulted in high chlorine demand at the plant, quick chlorine decay, low chlorine residuals and in turn bacterial regrowth in the distribution system. In addition, the reaction of chlorine with DOC led to the formation of elevated concentrations of disinfection by-products.

In order to improve treated water quality Barwon Water worked with Orica in piloting the MIEX® process in 2001. The trials proved the MIEX® process to be effective in:-
– removing the lower weight organics that are not accessible to ordinary coagulants;
– halving the required Alum dose;
– reducing THM (disinfection by-product) formation from approx 200ug/L to approx 100 ug/L (ADWG 250ug/L, USEPA 80ug/L); and
– reducing the required chlorine dose.

MIEX Pretreatment

As a result of the successful trials, a 1.5 MLD MIEX® plant was commissioned at Aireys Inlet in December 2004.

The MIEX® plant is located at the head of the conventional treatment process. The inlet works allow the flexibility of providing the conventional plant with 100% MIEX® treated water or a blend of raw and MIEX® treated water.

Raw Water Quality

Table 1 shows the historical raw water quality before the MIEX® Plant was installed. Note that while historical data is not available for raw water DOC, the amount of DOC that constitute total organic carbon (TOC) is approximately 85% at this site.

Table 1: Historical Water Quality Pre MIEX® Plant Installation

	TOC (mg/L)	UVA* (cm^{-1})	Colour (PCU)	SO_4^{-2} (mg/L)	Fe (mg/L)	Mn (mg/L)	TDS (mg/L)	Turbidity (NTU)
Average	11	0.47	49	8.5	1.3	0.05	190**	8.7
Minimum	4	0.19	21	5.5	0.05	0.01		1.6
Maximum	15	0.80	80	13	3.6	0.37		24

*Ultraviolet Absorbance at 254 nm (UVA)
**Only one reading available

While seasonal changes are expected in surface water sources, heavy rainfall in February 2005 caused the level of organic material to increase beyond historical levels. Since the MIEX® Plant was installed in December 2004, its treatment capabilities have been challenged by "worse case scenario" raw water quality beyond design criteria. The current raw water quality is summarised in Table 2.

Table 2: Water Quality Post MIEX® Plant Installation

	TOC (mg/L)	DOC (mg/L)	UVA* (cm^{-1})	Colour (PCU)	Fe (mg/L)	Mn (mg/L)	TDS (mg/L)	Turbidity (NTU)
Average	18	17	0.84	93	2.6	0.09	249	22
Minimum	14	14	0.62	62	0.9	0.01	180	1
Maximum	24	23	1.20	120	4.6	0.73	430	79

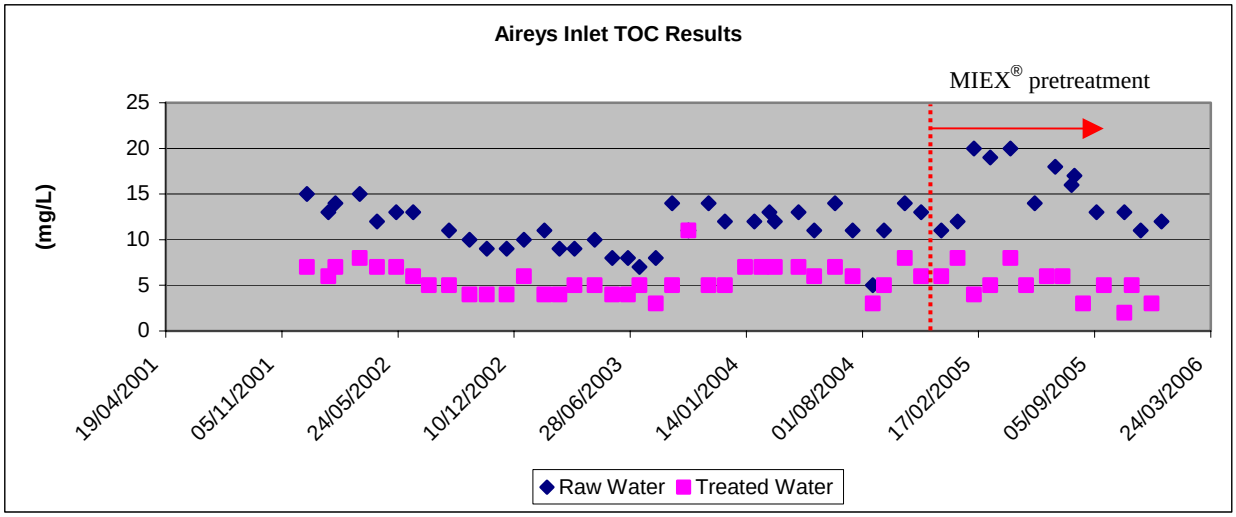
PROCESS PERFORMANCE DATA

Despite "worse case scenario" raw water quality the MIEX® Plant has performed extremely well. Process performance is outlined in the following sections.

Water Quality

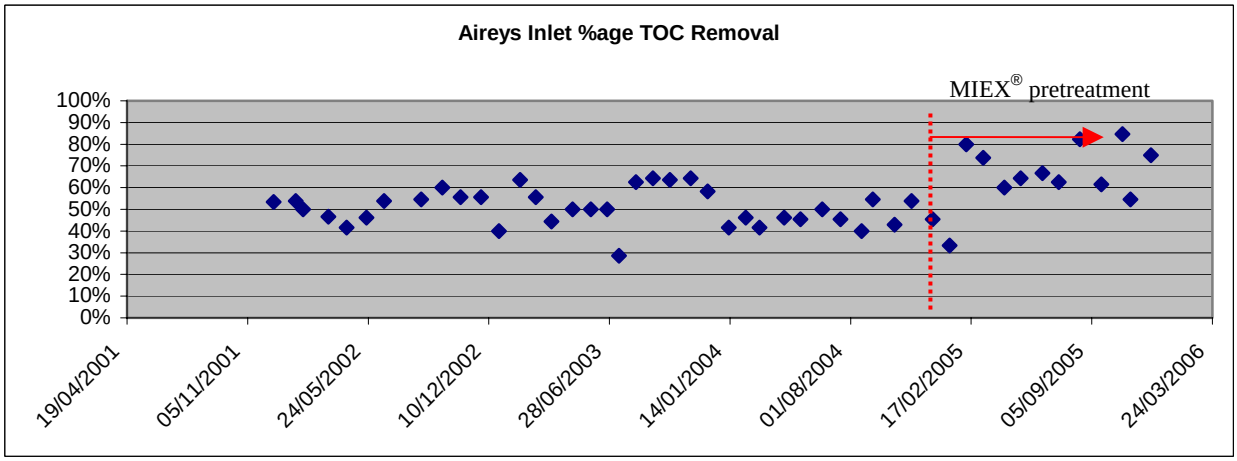
Total Organic Carbon

Since the MIEX® Plant has been installed treated water TOC levels have been between 2 and 8 mg/L despite raw water levels reaching 20 mg/L. Comparison of TOC and DOC levels show that DOC constitutes 85% of the TOC. Graph 1 compares raw and treated water TOC levels.



Graph 1: Aireys Inlet TOC Levels

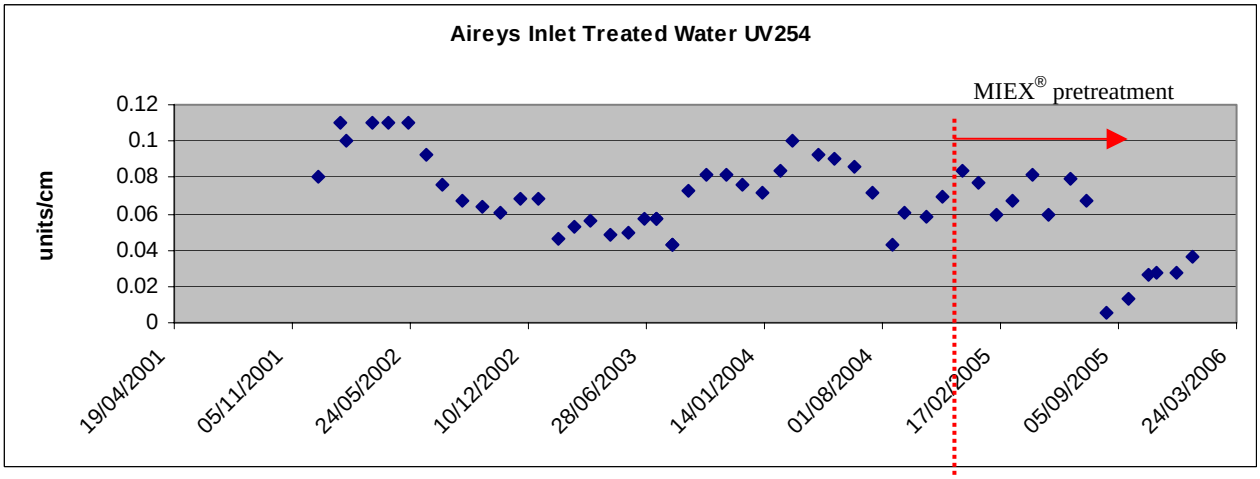
MIEX® has increased the percentage TOC removal from between 40-50% up to 60-80%. Graph 2 provides TOC removal percentages since 2001.



Graph 2: Aireys Inlet Percentage TOC Removal

UV Absorbance

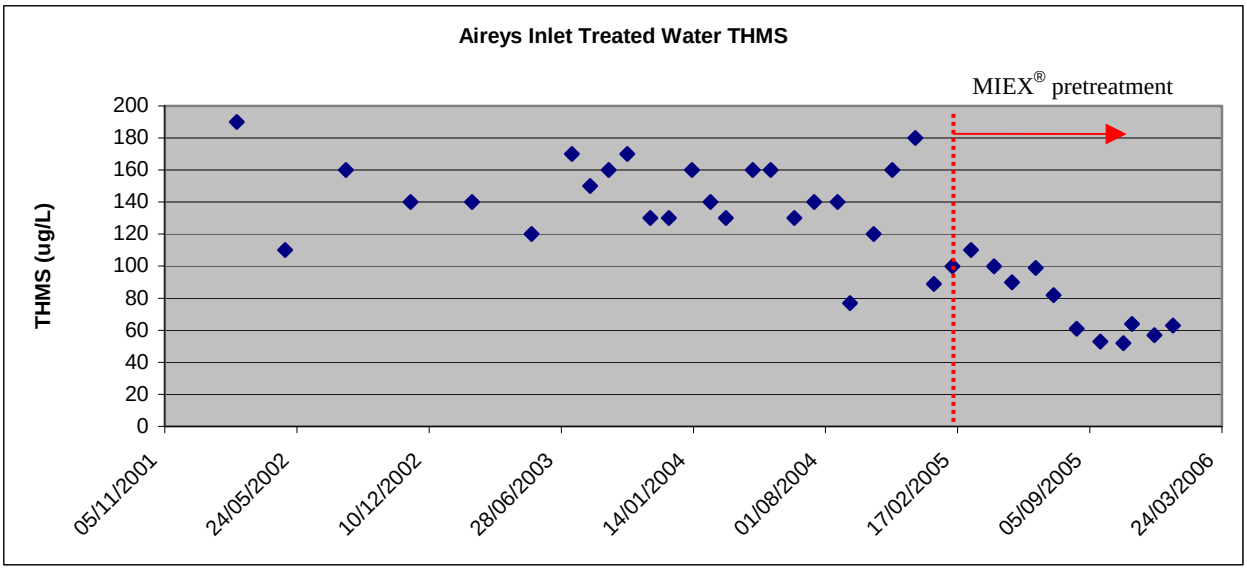
The raw water UV Absorbance (UVA) was approximately 1.0 between February and August 2005, 25% higher than any historical data and more than double the average historical level. Despite the high raw water UVA levels, treated water UVA levels over this period were similar to historical treated water UVA levels. As raw water quality has improved towards the end of 2005 and in early 2006 treated water UVA levels have been below 0.04 units/cm. UVA data is provided in graph 3.



Graph 3: Aireys Inlet Treated Water UVA

Disinfection By-Products

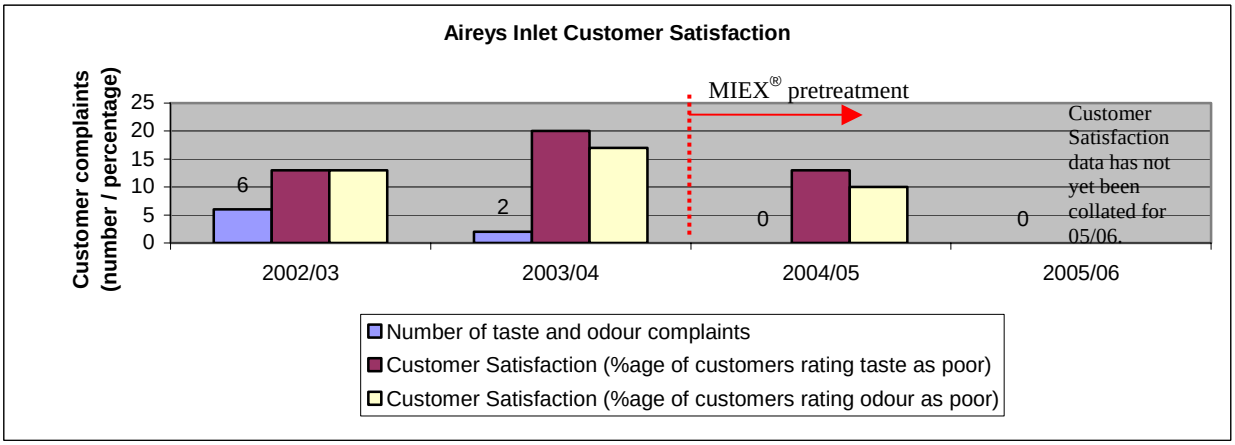
Increased DOC removal has reduced disinfection by-product pre cursors. MIEX® treatment has reduced THM levels below the limits of US EPA's Stage 1 Disinfection By Product Rule. THM data since 2001 is provided in graph 4.



Graph 4: Aireys Inlet Treated Water THMS

Customer Satisfaction

Treated water taste and odour has been improved through increased DOC removal and the subsequent reduced requirement for chlorine dosing. This improvement has been reflected in taste and odour complaint numbers and annual customer satisfaction surveys, as outline in graph 5.

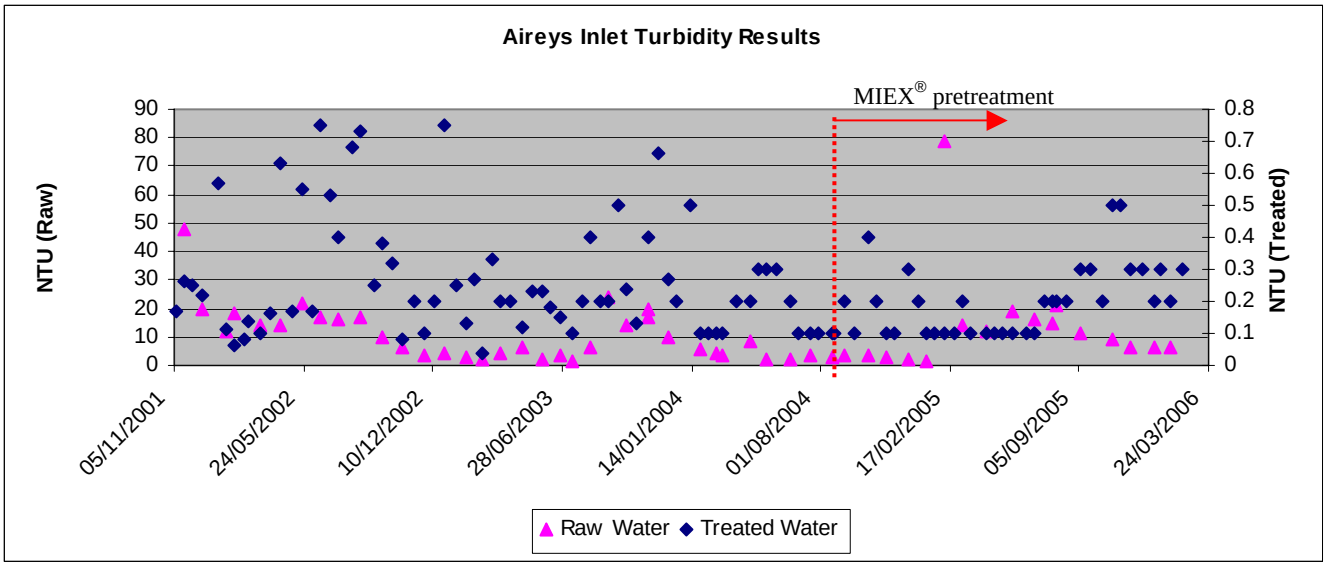


Graph 5: Aireys Inlet Customer Satisfaction

Plant Operation

Plant stability

Lowering the DOC concentration of water entering the conventional coagulation plant has improved clarifier stability in terms of chemical dosing and effluent turbidity. Before the MIEX® Plant was installed, jar testing was required regularly to determine the chemical demand of raw water entering the clarifier. Since the MIEX® Plant was installed, stability in the water quality entering the clarifier has significantly improved, resulting in the ability to operate the plant with a constant chemical dose rate. The turbidity results in Graph 6 below demonstrate the improved stability of the conventional plant's operation, in particular during periods of poor raw water quality.



Graph 6: Turbidity Results Across MIEX® and Coagulation

The MIEX® Plant requires little process adjustment. The key control parameters of the MIEX® process are the resin concentration, contact time and regeneration frequency. Operational decisions regarding these parameters are made on a weekly basis.

MIEX® Plant performance is monitored through an on-line UV 254 monitor and electrical conductivity probe.

Chemical consumption

The reduction in chemical consumption resulting from the MIEX® DOC removal is outlined in table 3.

Table 3: Aireys Inlet Conventional Plant Chemical Consumption

Chemical	Pre MIEX® Dose (mg/L)	Post MIEX® Dose (mg/L)
Alum	70-75 as Al_2O_3	30-35 as Al_2O_3
Soda Ash – pre coagulation	14	4.5
Soda Ash – post coagulation	35	20
Sodium Hypochlorite	5	1.8

Waste Production

Saline wastewater is produced through the regeneration process. The waste stream is produced at two different salt concentrations:-

- Approximately 700L of a dilute NaCL solution is generated per ML treated. This is disposed to sewer where it is diluted with domestic flows, treated and reused through tree-lot irrigation. In locations where sewer is not available, this stream is recycled to the head of the plant for treatment.
- Approximately 300L of 70g/L NaCL waste solution is generated per ML treated. This is stored in an on-site lagoon where it is evaporated or later transported to a wastewater treatment plant with ocean outfall. Recently a 'Waste Brine Recovery Unit' has been installed at Aireys Inlet which is recovering 100% of this stream for re-use within the regeneration process. This is achieved by coagulating out the organic material that has been stripped from the MIEX® Resin.

Operating Costs

As a result of fine tuning the MIEX® Plant during the first year of operation, it is difficult to provide accurate long-term stable operating costs.

Cost inputs, in addition to the conventional treatment process, include MIEX® Resin, salt and power. The additional power costs are minimal.

Cost savings include reduced chemical consumption through the conventional process and reduced distribution management costs (i.e flushing, air scouring and customer complaint responses).

Overall the operation of the MIEX® Plant has resulted in only a modest increase in water treatment operating costs.

CONCLUSIONS

Installation of a MIEX® Plant at Aireys Inlet has:-

- Increased DOC removal from 40-50% to 60-80%;
- Reduced THM levels by approximately 60% to levels below the requirements of the US EPA Disinfection By-Product Rule Stage 1;
- Improved the operational stability of the downstream conventional treatment process; and
- Improved customer satisfaction.

This has been achieved despite a significant deterioration in raw water quality and without a significant increase in operational costs.

ACKNOLEDGEMENTS

The authors wish to thank the staff at Barwon Water and Orica involved in the MIEX® Plant operations and technology development.