WATER RESEARCH 45 (2011) 1539–1548

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ScienceDirect

journal homepage: www.elsevier.com/locate/watres

Long term case study of MIEX pre-treatment in drinking water; understanding NOM removal

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ARTICLE INFO

Article history:
Received 25 June 2010
Received in revised form
18 November 2010
Accepted 18 November 2010
Available online 24 November 2010

Keywords:
MIEX
Coagulation
Microfiltration
NOM
Fractionation
Molecular weight

ABSTRACT

Removal of natural organic matter (NOM) is a key requirement to improve drinking water quality. This study compared the removal of NOM with, and without, the patented magnetic ion exchange process for removal of dissolved organic carbon (MIEX DOC) as a pre-treatment to microfiltration or conventional coagulation treatment over a 2 year period. A range of techniques were used to characterise the NOM of the raw and treated waters. MIEX pre-treatment produced water with lower concentration of dissolved organic carbon (DOC) and lower specific UV absorbance (SUVA). The processes incorporating MIEX also produced more consistent water quality and were less affected by changes in the concentration and character of the raw water DOC. The very hydrophobic acid fraction (VHA) was the dominant NOM component in the raw water and was best removed by MIEX pre-treatment, regardless of the raw water VHA concentration. MIEX pre-treatment also produced water with lower weight average apparent molecular weight (AMW) and with the greatest reduction in complexity and range of NOM. A strong correlation was found between the VHA content and weight average AMW confirming that the VHA fraction was a major component of the NOM for both the raw water and treated waters.

1. Introduction

Natural organic matter (NOM) has a significant impact on drinking water quality either directly, by reacting with water treatment chemicals (to form disinfection by-products), or indirectly, by impacting water treatment processes (including fouling of membranes and reducing the effectiveness of activated carbon for contaminant removal). Therefore the water industry has focussed on improving current treatment and developing new processes to increase the removal of NOM. Conventional treatment comprising coagulation/flocculation/sedimentation/filtration is one of the most widely used methods to remove NOM. Extensive research has been undertaken to increase the extent of NOM removal by conventional treatment, including the use of increased coagulant doses and reduced pH, referred to as enhanced coagulation (Crozes et al., 1995; White et al., 1997; Bell-Ajy et al., 2000). A more recent technology developed specifically for the removal of NOM is the patented MIEX DOC Process (Morran et al., 1996; Drikas et al., 2002). This process utilises a strong base anion-exchange resin, incorporating magnetic iron oxide particles within its core, which is applied to raw water utilising a stirred contactor. The small resin beads facilitate rapid reaction whilst the magnetic component allows separation of the resin and recycling of the resin in a continuous process. This differs from other more traditional applications where ion exchange resin is applied as the final polishing step within a filter (Brattebo et al., 1987; Baker et al., 1995). Laboratory scale testing of the MIEX resin has proven the effectiveness of the process for rapid removal of NOM, to a greater extent than that

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0043-1354/$ – see front matter
doi:10.1016/j.watres.2010.11.024

possible by coagulation, or enhanced coagulation, in a range of waters (Drikas et al., 2002, 2003a; Singer and Bilyk, 2002; Morran et al., 2004; Fearing et al., 2004; Humbert et al., 2005; Boyer and Singer, 2005). Some studies have also been conducted comparing pilot plant or full scale MIEX treatment with coagulation (Drikas et al., 2003b; Allpike et al., 2005; Boyer and Singer, 2005; Warton et al., 2007; Singer et al., 2007, 2009; Jarvis et al., 2008) although all of these studies have been conducted over a short period of time. A few studies have also assessed the effectiveness of MIEX as a means of reducing fouling of microfiltration or ultra filtration membranes (Fabris et al., 2007; Humbert et al., 2007; Dixon et al., 2010). MIEX has been shown to remove both hydrophobic and hydrophilic organic acid fractions of NOM (Singer and Bilyk, 2002; Morran et al., 2004; Fearing et al., 2004; Boyer and Singer, 2005; Mergen et al., 2008, 2009) to a greater extent than possible with coagulation alone. MIEX was also found to remove a wider range of molecular weight components than coagulation with alum (Drikas et al., 2003a, b; Morran et al., 2004; Allpike et al., 2005; Humbert et al., 2005; Singer et al., 2007).

The first MIEX plant was commissioned at Mt Pleasant in South Australia in August 2001 (Drikas et al., 2003b). The Mt Pleasant Water Treatment Plant (WTP) is a small (2.5 ML/d) potable water treatment plant supplying high quality treated water to the local community. However the plant is more complex, innovative and diverse in processes than necessary to enable the MIEX DOC process to be fully evaluated. The WTP has been divided into two streams of 1.25 ML/d capacity, each incorporating the MIEX DOC process but the plant also enables comparison of two separate subsequent processes for the removal of suspended matter – conventional treatment (comprising coagulation, flocculation, sedimentation, and filtration) and submerged microfiltration (MF) (Drikas et al., 2003b). This study enabled an extended evaluation of the impact of the MIEX DOC process on NOM removal by comparing the performance of the two processes operating at the Mt Pleasant WTP with separate pilot plant installations utilising the same processes (conventional treatment and submerged MF) but without MIEX pre-treatment, over a 2 year period. A quantitative assessment of the NOM removed by all the treatment processes was undertaken together with a detailed study of the character of the remaining NOM using a rapid fractionation technique and molecular weight profiles for 16 months of this period. This study has identified novel benefits of the continuous operation of the MIEX DOC process and provided a clearer understanding of the character of the NOM removed.

2. Materials and methods

2.1. *Treatment processes*

A schematic of the treatment trains used is provided in Fig. 1. A conventional pilot plant (Conv) consisting of coagulation, flocculation, sedimentation and rapid filtration was established on site at the Mt Pleasant WTP using the same raw water that supplied the WTP. The flash mixer was a vessel of 1.5 L volume which was stirred at a rate of 200 rpm with a flat paddle agitation blade. Alum was dosed directly into the top of this vessel via a piston dosing pump incorporating a flow dampening device. The two flocculation bays held 45 L each and were separated by a plate which the water laundered over. The first vessel was stirred at 80 rpm and the second at 40 rpm by an overhead stirrer with 25° offset flat paddles. Three 50 mm pipes delivered flocculated water into the 65 L sedimentation bay. The inverted pyramid shaped sedimentation bay allowed sludge to be collected over three days and be drained off to waste. Settled water was laundered from the top of the sedimentation bay via flexible beverage tubing which ran to a peristaltic pump. The pipe was split into three via a manifold in order to reach the desired flow rate and pumped via three peristaltic heads to the top of the filter column. The filter column consisted of a 140 mm diameter acrylic column and was filled with 600 mm of gravel (of varying grades), with 300 mm of sand of size 0.5–0.6 mm and 750 mm anthracite of size 1.0–1.1 mm. The media was of the same type and depth as the filters on Stream 1 of the Mt Pleasant WTP. The conventional pilot plant operated for three days on and four days off. The pilot plant throughput was 36 L/h which gave 2.5 h flocculation and 2 h settling time. The alum dose was 40 mg/L (as $Al_2(SO_4)_3 \cdot 18H_2O$) over the study period. This was selected by the use of a model (van Leeuwen et al., 2005) and confirmed by regular jar tests to achieve the optimum DOC removal (defined as the point of diminishing return, where an additional 10 mg/L alum produces <0.1 mg/L DOC reduction). The pH was not optimised but was between 6.5–6.8 throughout the study.

Conventional treatment (Conv) was compared with Stream 1 at the Mt Pleasant WTP which incorporates MIEX followed by conventional treatment comprising coagulation, flocculation, sedimentation, rapid filtration (MIEX Coag) (Fig. 1). During the period July 2005 to June 2007, MIEX was applied to maintain the resin dose at or above 10 mL/L for 10 min contact followed by sedimentation and removal of the resin before entering the separate particulate removal processes. The actual resin dose varied between 8 and 16 mL/L (average 12 mL/L) over this period. The resin was recirculated in a continuous process with 10% removed for regeneration using sodium chloride. Fresh regenerated resin was returned continuously to the resin contact tank to maintain a constant resin dose while regeneration was undertaken separately on a batch process as required. Virgin makeup resin was added on an infrequent basis to compensate for resin lost due to attrition. Coagulation in Stream 1 during this period varied between 6 and 10 mg/L (average 8 mg/L) (as $Al_2(SO_4)_3 \cdot 18H_2O$) and 0.2 mg/L poly dimethyl diallyl ammonium chloride (DADMAC) as a coagulant aid to ensure filtered water turbidity was maintained below 0.2 NTU. The throughput of Stream 1 at Mt Pleasant WTP remained steady at 0.3 ML/day which gave 3.5 h flocculation and 1.5 h settling time prior to filtration. Filter run times averaged 2 days.

The second stream at the Mt Pleasant WTP incorporates MIEX followed by submerged continuous microfiltration (CMF-S) with polyvinylidenefluoride (PVDF) membranes which have a nominal pore size of 0.04 μm (Memcor S10 V). However the MF pilot plant was used to provide the comparison of MF with and without MIEX pre-treatment to ensure operating conditions were identical for both operating systems. The MF pilot plant consisted of a single module CMF-S membrane, the same variety as that used in the Mt Pleasant WTP. Two separate membrane modules were used in the MF pilot plant unit in a one week on, one week off rotation. The source water for