Desalination 365 (2015) 196–203

Contents lists available at ScienceDirect

Desalination

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

Performance of a vibratory shear membrane filtration system during the treatment of magnetic ion exchange process concentrate

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HIGHLIGHTS

- Vibratory shear enhanced processing evaluation for the first time on magnetic ion exchange process concentrate.
- Fouling prior to cleaning-in-place every 14 batches leads to lengthened batch times.
- With 75%, 80% and 85% batch recoveries, more than 98% removal of DOC in MIEX waste was achieved.

ARTICLE INFO

Article history:
Received 16 December 2014
Received in revised form 25 February 2015
Accepted 26 February 2015
Available online 10 March 2015

Keywords:
Membrane nanofiltration
Magnetic ion exchange
MIEX
Vibratory shear enhanced process
VSEP

ABSTRACT

The performance of a vibratory shear enhanced processing (VSEP) unit used to treat waste generated from a magnetic ion exchange (MIEX) process is assessed. The unit was fitted with a NF-270 membrane (97% nominal rejection of $MgSO_4$) with an internal membrane surface area of 37 m^2. The vibration amplitude of the module was set at 12.7 mm. The system removes greater than 97% dissolved organic carbon as well as 70 − 85% multivalent solutes (Mg^{2+}, Ca^{2+}, SO_4^{2-}) from the MIEX waste. The permeate generated was high in salt and was successfully recycled to reduce the brine requirement for MIEX resin bead regeneration. Early operation in recirculating batch mode examined the effect of volumetric recoveries (in the permeate) ranging from 75–85%. Higher recovery had no significant influence on the performance of the system. System chemical cleaning was carried out every 14–16 batches. Batch durations generally extended in each subsequent cycle prior to cleaning, with the last batches taking up to five times longer than the first batch. The installation of VSEP has resulted in a reduced frequency of waste disposal from the facility and has also reduced the amount of make-up brine required for resin regeneration by 78%.

1. Introduction

In practice, inland groundwater treatment is significantly more complex than seawater desalination [1]. Seawater desalination operations utilise reverse osmosis to remove salts from sea water. Concentrate formed by desalination processes can be directly discharged into the ocean as there is little effect on the overall salinity of the ocean [2]. On the other hand, inland water treatment does not offer a straightforward method of concentrate disposal.

Concentrates generated as waste from inland water treatment plants are complex, and depending on the technology used, the final composition of the concentrate can vary significantly [3]. The concentrate may contain organic compounds, inorganic salts, microbacterium and viruses [4]. Incorrect discharge of concentrate has the potential to damage the environment, reduce public acceptance and present financial risks through penalties [5]. Concentrate discharge to surface waters can affect the temperature, salinity and concentration of the receiving water.

Inefficient purification processes can result in the deterioration of water quality in a number of aspects. Although there are few published reports linking organic pollutants and health effects, the presence of low molecular weight hydrocarbons does give rise to problems in drinking water [6]. Microbial contamination of drinking waters via waterborne pathogens has the potential to cause severe diarrhoeal diseases [7].

Dissolved organic matter is difficult to remove via conventional water treatment technologies [8]. Although membrane filters can effectively remove effluent organics from waste water streams, membrane fouling remains a significant drawback [9]. To ameliorate membrane fouling, additional processes such as flocculation, adsorption and ion exchange have been explored to remove organic matter from bulk water

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http://dx.doi.org/10.1016/j.desal.2015.02.042

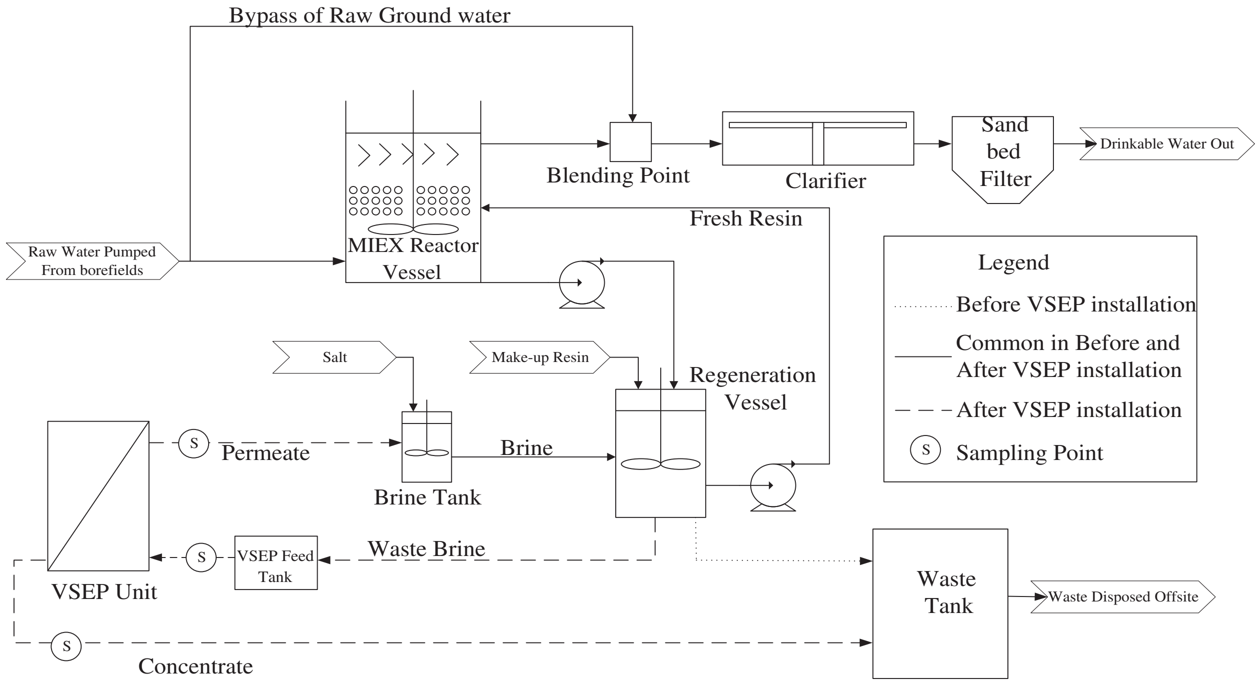

Fig. 1. The general layout of Wanneroo GWTP. Raw water is treated by the MIEX reactor vessel and sent to the clarifier and bed filters. Resin beads are regenerated in the regeneration vessel. Brine is a critical component in the regeneration process. The installation of VSEP at Wanneroo GWTP allows for MIEX waste concentrate to be treated and partially reused as make-up brine for the regeneration vessel. The MIEX waste prior to VSEP installation is sent to the waste tank (seen in the dotted line). Post-VSEP installation (dashed line) shows that VSEP concentrate is sent to the waste tank and the permeate is sent to the brine tank.

streams [10]. An example of an ion exchange system is the magnetic ion exchange process (MIEX) currently installed to treat groundwater at Wanneroo in Western Australia.

Magnetic ion exchange (MIEX) is a water treatment technology that uses magnetic beads to remove contaminants such as dissolved organic compounds from groundwater [11]. MIEX resins are approximately 180 μm in diameter. They provide high surface area for the rapid exchange of dissolved organic carbon (DOC) and chloride ions on the active sites of the resin. MIEX resins have been shown to remove more than 80% of DOC and 85% of UV absorbance from bulk raw waters [12]. Organic matter removed by the MIEX resins ranged from 500–1000 Da in molecular weight. Spent (i.e. fully loaded with organics) beads can be regenerated by mixing with highly concentrated salt solutions. Within this regeneration phase, MIEX waste is formed that is particularly highly concentrated in salt and organics.

At Wanneroo Groundwater Treatment Plant in Western Australia, Australia, the current method used to treat waste is blending. Blending is not a conventional way to treat concentrate. The technique involves mixing a concentrate stream such as MIEX waste with a less concentrated waste stream such as downstream filtrate to achieve a stream that is at a permissible concentration for direct discharge [13,14]. After blending, treated concentrate is collected in a waste tank for storage. Stored waste is later removed by a specialist company at significant cost.

To reduce the expense associated with concentrate disposal, the ideal approach is to eliminate or reduce the amount of waste produced. One option to do this is to employ volume reducing technology known as vibratory shear-enhanced processing (VSEP), which uses dynamic filtration to improve flux and control fouling phenomena [15]. The vigorous vibrational motion generates shear waves that act along the membrane surface to lift solids and foulants away from the surface and into the bulk flow. In the past, VSEP has been utilised in the paper milling, yeast treatment, dairy and water treatment industries [16].

A recent study by Nurra et al. utilised VSEP in order to dewater microalgae for use in biodiesel production [17]. Membrane filtration demonstrated more suitability as they did not disrupt fragile cells, unlike the centrifugation. The study compared the use of VSEP to conventional cross-flow filtration technology. Results showed that the dynamic forms of filtration were able to achieve high permeabilities and permeate flow rates, in some cases doubling that of conventional filtration that was attributed to the elimination of fouling. The filter pack consists of stacked circular membranes separated by gaskets and permeate collectors. The vertical shaft is spun in azimuthal oscillations that vibrate the base of the filter pack. The generated shear varies sinusoidally with time and it is the use of this resonance which minimizes the power requirements for vibration formation.

Vaneeckhaute applied VSEP technology to remove macronutrients from digestate, a product produced from co-digestion of animal manure [18]. The primary functionality of the VSEP was to remove macronutrients ranging from nitrogen, phosphorus, potassium, sodium, calcium and magnesium. Filtration via VSEP was able to remove 93% of nitrogen and 59% of phosphorus.

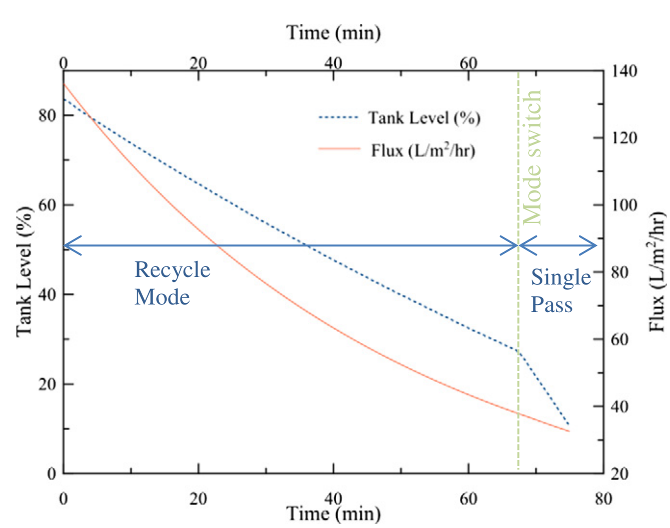

Fig. 2. The flux change over the course of a VSEP batch.