Journal of Environmental Management 151 (2015) 540–549

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Effects of different pretreatments on the performance of ceramic ultrafiltration membrane during the treatment of oil sands tailings pond recycle water: A pilot-scale study

Kavithaa Loganathan [a, *], Pamela Chelme-Ayala [b], Mohamed Gamal El-Din [b, **]

[a] Canadian Natural Resources Ltd., Fort McMurray, Alberta T9H 3H5, Canada
[b] Department of Civil and Environmental Engineering, University of Alberta, Edmonton, Alberta T6G 2W2, Canada

ARTICLE INFO

Article history:
Received 7 November 2014
Received in revised form
8 January 2015
Accepted 10 January 2015
Available online 14 January 2015

Keywords:
Ultrafiltration
Ceramic membrane
Pretreatment
Oil sands
Recycle water

ABSTRACT

Membrane filtration is an effective treatment method for oil sands tailings pond recycle water (RCW); however, membrane fouling and rapid decrease in permeate flux caused by colloids, organic matter, and bitumen residues present in the RCW hinder its successful application. This pilot-scale study investigated the impact of different pretreatment steps on the performance of a ceramic ultrafiltration (CUF) membrane used for the treatment of RCW. Two treatment trains were examined: treatment train 1 consisted of coagulant followed by a CUF system, while treatment train 2 included softening (Multiflo™ system) and coagulant addition, followed by a CUF system. The results indicated that minimum pretreatment (train 1) was required for almost complete solids removal. The addition of a softening step (train 2) provided an additional barrier to membrane fouling by reducing hardness-causing ions to negligible levels. More than 99% removal of turbidity and less than 20% removal of total organic carbon were achieved regardless of the treatment train used. Permeate fluxes normalized at 20 °C of 127–130 L/m^2 h and 111–118 L/m^2 h, with permeate recoveries of 90–93% and 90–94% were observed for the treatment trains 1 and 2, respectively. It was also found that materials deposited onto the membrane surface had an impact on trans-membrane pressure and influenced the required frequencies of chemically enhanced backwashes (CEBs) and clean-in-place (CIP) procedures. The CIP performed was successful in removing fouling and scaling materials such that the CUF performance was restored to baseline levels. The results also demonstrated that due to their low turbidity and silt density index values, permeates produced in this pilot study were suitable for further treatment by high pressure membrane processes.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Oil sands tailings pond recycle water (RCW), also known as oil sands process-affected water, is a very complex mixture of suspended solids, salts, inorganic compounds, organic compounds, and trace metals generated after the extraction of bitumen from the sands (Allen, 2008; Holowenko et al., 2002). Organic compounds found in RCW include naphthenic acids (NAs), benzene, humic and fulvic acids, and polycyclic aromatic hydrocarbons (PAHs), among others (Allen, 2008; Grewer et al., 2010). Under no-release policy, operating companies store RCW in tailing ponds in order to avoid its release into the receiving environment (Giesy et al., 2010; MacKinnon, 1989). High demand for fresh water and suitable water quality in both the conventional oil and gas operations and in the Alberta's unconventional gas and oil sands (*in-situ* and mining) production mandate a continuous search for reliable and cost-effective technologies for the treatment of RCW.

Various physical, chemical, and biological treatments have been assessed to develop cost-effective strategies for RCW remediation (Drzewicz et al., 2012; Gamal El-Din et al., 2011; He et al., 2010; Islam et al., 2014; Kim et al., 2013; Peng et al., 2004; Pourrezaei et al., 2014, 2011; Zubot et al., 2012). Natural *in situ* microbial degradation in tailings ponds has proven to be very slow (Han et al.,

* Corresponding author. Technology Development-Horizon Oil Sands, Canadian Natural Resources Ltd., Fort McMurray, AB T9H 3H5, Canada.
** Corresponding author. NSERC Senior Industrial Research Chair in Oil Sands Tailings Water Treatment, Helmholtz – Alberta Initiative Lead (Theme 5), Department of Civil and Environmental Engineering, University of Alberta, Edmonton, Alberta T6G 2W2, Canada.
E-mail addresses: Kavithaa.Loganathan@cnrl.com (K. Loganathan), mgamaleldin@ualberta.ca (M. Gamal El-Din).

http://dx.doi.org/10.1016/j.jenvman.2015.01.014
0301-4797/© 2015 Elsevier Ltd. All rights reserved.

2009). Ozonation has been found to degrade acid-extractable fraction and increase RCW biodegradability (Gamal El-Din et al., 2011). Fluidized bed biofilm reactors with granular activated carbon as support media have been found to be promising treatment methods for RCW remediation (Islam et al., 2014). Significant removal of acid-extractable fraction (up to 94%) and toxic reduction towards *Vibrio fischeri* and rainbow trout have been reported using petroleum coke adsorption (Zubot et al., 2012). Among physical treatments, membrane filtration has been found to be an effective method of removing ionic species from RCW (Alpatova et al., 2014; Kim et al., 2011). However, the successful application of membrane filtration for RCW treatment is hindered by membrane fouling and rapid decrease in permeate flux caused by colloids, organic matter, and bitumen residues that adhere to the surface and pores of the membrane (Kim et al., 2011, 2012; Peng et al., 2004). Pretreatment methods such as coagulation, flocculation and sedimentation have been used to reduce foulants such as suspended and dissolved solids (Kim et al., 2011). Coagulation of RCW has been shown to destabilize suspended solids and colloidal matter by reducing their surface charge and promoting their coalescence, leading to flocs formation during the flocculation process (Kim et al., 2012; Pourrezaei et al., 2011), while sedimentation has been reported to remove the generated flocs (Kim et al., 2011, 2012).

Due to their excellent chemical resistance to inorganic acids and oxidants, the tolerance to high temperatures and longer lifespan (AWWA, 1996; Byun et al., 2011; Karnik et al., 2005), the application of ceramic membranes for water and wastewater treatment has increased over the last decades (Cui et al., 2011; Guerra et al., 2012; Xu et al., 2010; Zhu et al., 2012). Several studies using ceramic membranes have been conducted to treat oil-containing wastewater and process water (Abadi et al., 2011; Deriszadeh et al., 2010; Lobo et al., 2006; Sadeghian et al., 2010). These studies have shown that ceramic membranes perform better than polymeric membranes on oil-containing waters. In the present study, a pilot-scale investigation was conducted to assess the impact of different pretreatment methods on the performance of a ceramic ultrafiltration (CUF) membrane system used to effectively treat RCW from an oil sands facility and achieve water quality requirements to feed unit effluent to a reverse osmosis (RO) system. Two treatment trains were assessed: treatment train 1 consisted of coagulant addition followed by CUF system, while treatment train 2 included softening (Multiflo™ system) and coagulant addition, followed by a CUF system. Along with the optimization of system performance, other objectives for the pilot-scale study were: (1) to determine the optimum ranges for operating parameters that impacted the CUF system performance, including permeate flux and maximum sustainable recovery rates; (2) to evaluate the effect of hydrodynamic conditions such as trans-membrane pressure (TMP) on the membrane filtration performance; and (3) to evaluate the membrane fouling caused by RCW under the different treatment trains and cleaning procedures.

2. Materials and methods

2.1. Recycle water

RCW from Canadian Natural Resources Limited (CNRL) Horizon operation was used as feed water for this pilot study. The water was drawn from a header of the main hydrocyclones of the CNRL cooling water recycle system. Water flowed from the RCW header to a 60-m^3 tank on the pilot site which was used to feed the pilot facility. The storage tank water was constantly recirculated in order to prevent the settling out of solids or the separation of hydrocarbon materials.

2.2. Pilot facility

The pilot facility was located on CNRL Horizon site, adjacent to 99A plant, which is on the north side of the site. The pilot study took place between October 7th, 2012 and February 9th, 2013. Two distinct treatment trains were tested to treat RCW. The treatment train 1 included coagulant addition (aluminum sulfate) followed by a CeraMem® CUF system. The CUF system consisted of two banks of ceramic membranes operated in parallel. Each bank contained two CUF elements operated in series. The CUF system was operated in dead-end mode with a constant reject waste stream (bleed flow). The CUF system was intended to remove the majority of the solids and free oil from the system as these were significant issues for the downstream RO system.

The treatment train 2 included a softening equipment (Multiflo™) followed by a CeraMem® CUF system. The Multiflo™ system consists of a series of reaction tanks followed by a crystallization tank with an integrated mixing system that facilitated the precipitation of hardness-causing ions in the feed water and crystallization of the solids generated. Crystalline solids were then settled using a lamella plate clarifier, also integrated into the Multiflo™ system. A portion of the settled solids were recycled to the front of the softening system to seed the precipitation process. The process equipment, including Multiflo™ softening system, chemical dosing systems, and CUF system was supplied by Veolia Water Technologies. Schematics of the treatment trains are provided in Fig. 1.

The treatment trains 1 and 2 used the same CUF pilot system and configuration. Titania membrane elements (CeraMem® FE-S2S-0100TO-D00-00) with a nominal average pore size of 0.1 μm were used. The membrane element length and diameter were 864 and 144 mm, respectively, while the membrane active surface area per element was 10.7 m^2. Chemically enhanced backwashes (CEBs) and clean-in-place (CIP) procedures were conducted using caustic soda, sodium hypochlorite, and citric acid according to the membrane manufacturer's recommendations.

2.3. Analytical sampling plan

Consistent and representative sampling was conducted daily by an on-site laboratory. An important aspect of this pilot-scale study was the collection of a continuous data set of key process parameters through the use of online instrumentation. The online instruments were linked to the pilot-plant SCADA system. On-site testing included pH, temperature, silt density index (SDI), turbidity,

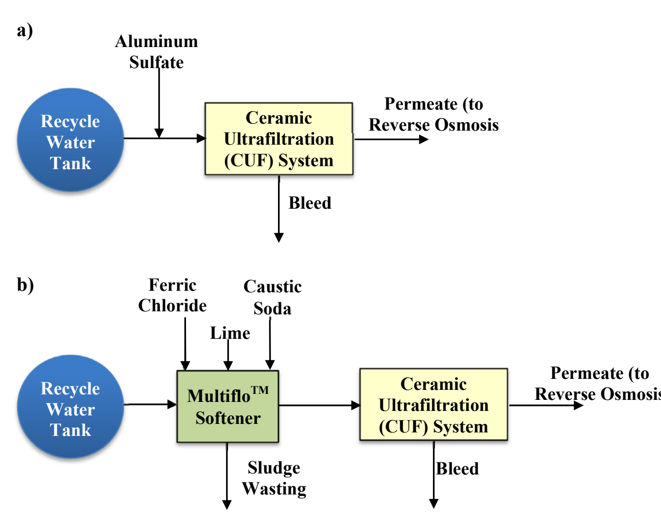

Fig. 1. Schematics of a) treatment train 1 and b) treatment train 2.

Download English Version:

https://daneshyari.com/en/article/7483210

Download Persian Version:

https://daneshyari.com/article/7483210

Daneshyari.com