WATER RESEARCH 63 (2014) 147–157

Available online at www.sciencedirect.com

ScienceDirect

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

Effect of biological activated carbon pre-treatment to control organic fouling in the microfiltration of biologically treated secondary effluent

Biplob Kumar Pramanik, Felicity A. Roddick, Linhua Fan*

School of Civil, Environmental and Chemical Engineering, RMIT University, GPO Box 2476, Melbourne 3001, Australia

ARTICLE INFO

Article history:
Received 3 February 2014
Received in revised form
22 May 2014
Accepted 11 June 2014
Available online 20 June 2014

Keywords:
Biological activated carbon
Biologically treated secondary effluent
Pre-treatment
Microfiltration
Organic fouling

ABSTRACT

Biological activated carbon (BAC) filtration was investigated as a pre-treatment for reducing the organic fouling of a microfiltration membrane (0.1 μm polyvinylidene fluoride) in the treatment of a biologically treated secondary effluent (BTSE) from a municipal wastewater treatment plant. BAC treatment of the BTSE resulted in a marked improvement in permeate flux, which was attributed to the effective removal of organic foulants and particulates. Although the BAC removed significantly less dissolved organic carbon than the granular activated carbon (GAC) treatment which was used as a control for comparison, it led to a markedly greater flux. This was attributed to the effective removal of the very high molecular weight substances such as biopolymers by the BAC through biodegradation and adsorption of those molecules on the biofilm. Size exclusion chromatography showed the BAC treatment led to approximately 30% reduction in these substances, whereas the GAC did not greatly remove these molecules. The BAC treatment led to a greater reduction of loosely-attached and firmly-attached membrane surface foulant, and this was confirmed by attenuated total reflection-fourier transform infrared spectroscopy analysis. This study demonstrated the potential of BAC pre-treatment for reducing organic fouling and thus improving flux for the microfiltration of BTSE.

1. Introduction

The use of low pressure membrane (LPM) technology such as microfiltration (MF) and ultrafiltration (UF) in municipal wastewater reclamation has increased over the past decade as it has many advantages over conventional filtration processes, such as high permeate quality, good reliability in operation and small footprint. However, organic fouling of the membranes remains a major issue limiting the efficiency of the reclamation processes. The fouling is usually due to the accumulation and/or adsorption of organic matter in the pores and/or on the surface of the membranes, which leads to the decline of the permeate flux or increase of operating pressure with processing time, resulting in higher operating costs. Effluent organic matter (EfOM) is considered to be the most significant membrane foulant in biologically treated wastewater effluent (BTSE); it contains polysaccharides, proteins, amino-sugars, nucleic acids, organic acids, humic materials, and cell components (Barker et al., 2000; Jarusutthirak

* *Corresponding author*. Tel.: +61 3 9925 2080; fax: +61 3 9639 0138.
E-mail address: felicity.roddick@rmit.edu.au (F.A. Roddick).
http://dx.doi.org/10.1016/j.watres.2014.06.014
0043-1354/

et al., 2002). The interaction between these organics and membranes leads to hydraulically reversible and irreversible fouling of the membranes.

Some previous studies reported that hydrophilic organics caused serious flux decline for LPM treatment of secondary effluent (Fan et al., 2008; Zheng et al., 2010), while other studies reported that hydrophobic organics were largely responsible for fouling the membranes (Shon et al., 2006). Understanding of the organics responsible for the fouling is not clear due to the diversity and complexity of the foulants and membrane properties. In addition, particulate substances in BTSE may cause flux decline, and membrane permeate flux usually decreases with increasing turbidity in feed water (Nakatsuka et al., 1996). Hallé et al. (2009) and Peldszus et al. (2011) found that particulates can also play an important role in the formation of the fouling layer on membranes through combination with organic components.

To improve treatment performance, LPM processes may be coupled with feed pre-treatments such as coagulation, ozonation, adsorption by granular activated carbon (GAC), powdered activated carbon or anion exchange resin, or slow sand filtration. Nguyen and Roddick (2013) found that treatment with powdered activated carbon (150 mg/L, 30 min contact time) or anion exchange resin (10 ml/L, 20 min contact time), could remove dissolved organic matter but did not affect the membrane flux due to their ineffectiveness in removing highly fouling potential compounds such as biopolymers. Biological treatment processes are considered a possible cost effective pre-treatment (Huck and Sozański, 2008; Hallé et al., 2009) as they can effectively improve LPM performance. Marco et al. (1997) also noted that capital and operating costs of biological treatment processes are 5–20 and 3–10 times cheaper than chemical processes, respectively. Zheng et al. (2009) utilised a slow sand filter as a pre-treatment for a secondary effluent prior to UF, and showed that the major foulants (biopolymers such as proteins and polysaccharides) were removed and thus the flux was improved. They also observed that humic substances, which are widely regarded as important foulants of LPM membranes, were not greatly removed by the pre-treatment, which was likely due to the low surface area and thus low adsorption capacity of sand media. Therefore, biological activated carbon (BAC) could be a better solution for the removal of organic matter due to simultaneous physico-chemical adsorption of humic substances by the activated carbon and biodegradation of biopolymers by the bacteria attached to the carbon particles. GAC has a much higher effective surface area than the anthracite and sand generally used in slow sand filters, and is suitable for adsorbing contaminant molecules and supporting a biofilm, increasing the possibility of a high biodegradation rate. Moreover, BAC is a cost effective process in terms of small footprint and low energy consumption (Walker and Weatherley, 1999). Nguyen and Roddick (2010) studied the effect of BAC after ozonation of effluent from an activated sludge process on UF and found that the flux was improved. This was attributed to partial oxidation of the high molecular weight (MW) organic components to low MW components by pre-ozonation and the utilization of some of the organics by the microorganisms in the BAC filtration. Yapsakli and Çeçen (2010) suggested that the need for ozonation may be avoided if the BAC treatment has a sufficiently long contact time to achieve biodegradation of slowly biodegradable organics, which could lead to a simpler and more cost-effective pre-treatment solution. Nevertheless, the impact of stand-alone BAC treatment of BTSE prior to LPM has not yet been investigated.

The aim of this study was to evaluate the efficiency of BAC treatment of a BTSE from a municipal wastewater treatment plant for improving the performance of MF. GAC pre-treatment of the BTSE was also conducted as a control for comparison with the BAC treatment.

2. Materials and methods

2.1. Source of BTSE

The BTSE was collected from a local wastewater treatment plant which uses activated sludge followed by a lagoon process to treat a municipal wastewater. The sewage is treated by passing through activated sludge ponds with anoxic and aerobic zones where bacteria break down the organic matter. The biologically treated effluent then passes through a clarifier and a series of lagoons before it is released to the environment. Samples were stored at 4 °C and warmed to room temperature (22 ± 2 °C) prior to all tests.

2.2. BAC and GAC column start-up and operation

The BAC and GAC columns were constructed of glass, with an internal diameter of 2.3 cm and effective bed height of 22 cm. The columns were operated in a continuous down flow mode with an empty bed contact time (EBCT) of 40 min. Columns were backwashed for 10 min every 14 days to reduce physical clogging of the media.

Prior to packing the BAC column, the activated carbon was inoculated with activated sludge, aerated and provided with additional nutrient sources (N, P and C) over 5 days to promote the growth of biofilm on the surface of the carbon. It was then washed with Milli-Q water to remove excess biofilm and transferred to a column, and BTSE feed was commenced. The reduction in dissolved organic carbon (DOC) was fairly constant (30 ± 3%) after 90 days operation, indicating that equilibrium had been established. For the control (GAC) column, sodium azide (0.1 mM) was added to the feed to a column of washed virgin GAC to inhibit microbial growth. The DOC removal efficiency was stable after 25 days of operation. The results reported are for samples collected after 196 days and 44 days of BAC and GAC operation, respectively.

2.3. Properties of granular activated carbon

Coal-based granular activated carbon (GAC 1300), recommended for BAC use by the supplier (Activated Carbon Technology), was used in this study. The specific surface area and pore size distribution of activated carbon samples (virgin, used GAC and BAC) were measured by adsorption–desorption isotherms of nitrogen at 77.15 K (Micromeritics ASAP 2000, USA). Prior to the measurements, the samples were degassed at 250 °C for 12 h under vacuum to remove moisture. The