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Effect of membrane bioreactor solids retention time on reverse osmosis membrane fouling for wastewater reuse

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ABSTRACT

The effect of the solids retention time (SRT) in a membrane bioreactor (MBR) on the fouling of the membranes in a subsequent reverse osmosis (RO) process used for wastewater reuse was studied experimentally using a pilot-scale treatment system. The MBR-RO pilot system was fed effluent from the primary clarifiers at a large municipal wastewater treatment plant. The SRT in the MBRs was adjusted to approximately 2, 10, and 20 days in three experiments. The normalized specific flux through the MBR and RO membranes was evaluated along with inorganic and organic constituents in the influent and effluent of each process. Increasing the SRT in the MBR led to an increase in the removal of bulk DOC, protein, and carbohydrates, as has been observed in previous studies. Increasing the SRT led to a decrease in the fouling of the MBR membranes, which is consistent with previous studies. However, the opposite trend was observed for fouling of the RO membranes; increasing the SRT of the MBR resulted in increased fouling of the RO membranes. These results indicate that the constituents that foul MBR membranes are not the same as those that foul RO membranes; to be an RO membrane foulant in a MBR-RO system, the constituents must first pass through the MBR membranes without being retained. Thus, an intermediate value of SRT may be best choice of operating conditions in an MBR when the MBR is followed by RO for wastewater reuse.

1. Introduction

Population growth and depletion of high quality fresh water supplies have led to an increased interest in wastewater reuse to augment potable water supplies either directly or indirectly. Membrane bioreactors (MBRs) provide excellent treatment with respect to traditional wastewater effluent parameters (biochemical oxygen demand, total suspended solids, turbidity, etc.) (Mohammadi et al., 2012; Abdel-Shafy et al., 2011) and produce effluent suitable for discharge to the environment and most non-potable reuse applications. However, transforming wastewater into potable water safe for human consumption warrants a higher level of treatment. Utilities that are considering direct or indirect potable water reuse may consider reverse osmosis (RO) as a technology that can provide the desired level of treatment.

The combination of membrane bioreactors with reverse osmosis is promising for the treatment of wastewater to potable water standards (Bonnelye et al., 2008). Reverse

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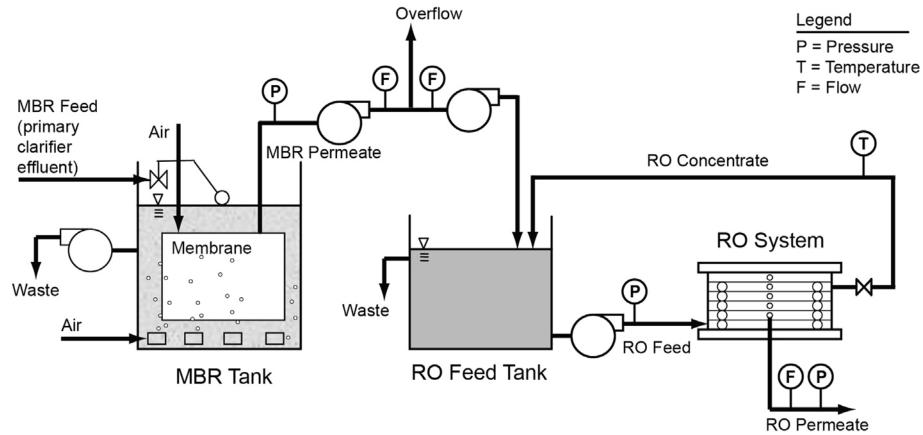

Fig. 1 – Schematic of the MBR-RO pilot plant.

osmosis can effectively remove total dissolved solids, ammonia, nitrate, bacteria, and viruses (Tam et al., 2007). RO has been shown to be one of the most effective water treatment processes in reducing ecotoxicity and genotoxicity of secondary treated municipal wastewater (Cao et al., 2009), is listed as a best available technology for many inorganic contaminants in the Safe Drinking Water Act, and has been demonstrated to be effective at removing pharmaceutical and personal care products (PPCPs) (Lee et al., 2012; Gur-Reznik et al., 2011; Alturki et al., 2010; Snyder et al., 2006).

Although MBR and RO are both established technologies, their use together for advanced wastewater treatment is currently not common. Experimental studies have shown that the MBR-RO process can be very effective at producing high quality water (Dolar et al., 2012; Qin et al., 2006; Comerton et al., 2005). It is reasonable to expect, however, that the operation of the MBR system may influence the operation of the RO system, and it is therefore prudent to investigate possible interactions that may affect the performance of both processes. Reverse osmosis performance is commonly impacted by membrane fouling—a process in which constituents in the feed water collect on the membrane surface and reduce the flow of water through the membrane. The general types of RO fouling are inorganic, particulate, biological, and organic fouling (Howe et al., 2012; AWWA Membrane Technology Research Committee, 2005). In MBR-RO systems, membrane fouling by inorganic scaling can be caused by calcium phosphate or silica (Moreno et al., 2013; Ogawa et al., 2010). Inorganic and particulate fouling of RO membranes can be managed by using appropriate pretreatment (cartridge filters or other processes to remove particles, pH adjustment, and antiscalants), limiting recovery, and periodic membrane cleaning. Biological and organic fouling can be more difficult to control.

Reverse osmosis membrane fouling in wastewater applications can be affected by the quality of the effluent from the biological process. Qin et al. (2006) and Jacob et al. (2010) compared RO membrane fouling when fed effluent from either conventional activated sludge with membrane filtration (CAS-MF) or a membrane bioreactor. Qin et al. (2006) found less RO membrane fouling from the MBR effluent than the CAS-MF effluent. Jacob et al. (2010) found that the lower TOC effluent from one MBR system caused less RO membrane fouling than the effluent from the CAS-MF system or a second MBR system with higher TOC effluent. RO membrane fouling may depend on how the MBR process is operated. The solids retention time (SRT) is a key operating parameter for MBR systems and affects the microbial communities in the bioreactor and permeate quality. It is well established that increasing the SRT decreases the fouling rates of MBR membranes (Liang et al., 2007; Su et al., 2011; Tian et al., 2012) and can change MBR permeate water quality (Innocenti et al., 2002). Extracellular polymeric substances (EPS), which are high molecular weight compounds that are secreted by microorganisms, play a significant role in MBR membrane fouling, particularly the polysaccharide and carbohydrate components (Dvořák et al., 2011; Kim et al., 2009; Zhang et al., 2006; Le-Cletch et al., 2006). Al-Halbouni et al. (2008) conducted experiments in which the foulant layer on MBR membranes was analyzed for EPS characteristics in terms of protein and carbohydrate concentrations at a typical SRT (23 days) and higher SRT (40 days). When operated at the lower SRT value, the MBR foulant layer contained a 5-fold higher carbohydrate concentration and a 40-fold higher protein concentration than when the MBR was operated at the higher SRT (Al-Halbouni et al., 2008). The SRT also affects microbial communities in the MBR, particularly organisms on or near the MBR membrane surface (Su et al., 2011; Ahmed et al., 2007; Cao et al., 2009; Zhang et al., 2006; Cicek et al., 2001).

Some organic constituents transformed during the MBR process are retained by the MBR membrane and contribute to MBR fouling, but other soluble organic constituents pass through the MBR membrane and are present in the MBR permeate. It is reasonable to expect that the operating conditions (e.g., SRT) in the MBR can affect the physicochemical properties of both the retained and permeating organic constituents. While the relationship between the SRT in the MBR and the rate of MBR fouling has been established, the relationship between the SRT in the MBR and the rate of RO membrane fouling has not been studied in previous research.

The specific objective of this research was to investigate the effect of the SRT in an MBR on the fouling of RO membranes in a subsequent RO process. In this study, permeate from pilot-scale MBRs operating at different SRTs was continuously fed