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Impact of SRT on the performance of MBRs for the treatment of high strength landfill leachate

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ABSTRACT

This study examines the performance and fouling potential of flat sheet (FS) and hollow fiber (HF) membrane bioreactors (MBRs) during the treatment of high strength landfill leachate under varying solid retention times (SRT = 5–20 days). Mixed-liquor bacterial communities were examined over time using 16S rRNA gene sequence analysis in an attempt to define linkages between the system performance and the microbial community composition. Similarly, biofilm samples were collected at the end of each SRT to characterize the microbial communities that evolved on the surface of the FS and HF membranes. In general, both systems exhibited comparable removal efficiencies that dropped significantly as SRT was decreased down to 5 days. Noticeably, ammonia and nitrite oxidizing bacteria were not detected at the tested SRTs. This suggests that the nitrifiers were not enriched, possibly due to the high organic and ammonium content of the leachate that led to low TN and NH_3 removal efficiency. The steady-state fouling rate of both membranes increased linearly with the decrease in SRT at an estimated factor of 1.1 and 1.2 for the FS- and HF-MBR, respectively, when the SRT was reduced from 15 to 10 days and from 10 to 5 days. Similar dominant genera were detected in both MBRs, including *Pseudomonas*, *Aequorivita*, *Ulvibacter*, *Taibaiella*, and *Thermus*. *Aequorivita*, *Taibaiella*; *Thermus* were the dominant genera in the biofilms. Hierarchical clustering and non-metric multidimensional scaling revealed that while the mixed liquor communities in the FS-MBR and HF-MBRs were dynamic, they clustered separately. Similarly, biofilm communities on the FS and HF membranes differed in the dynamic bacterial community structure, especially for the FS-MBR; however this was less dynamic than the mixed liquor community.

1. Introduction

Landfilling remains a common element of a waste management plan and at times the only element due to its relative simplicity and low cost when compared to other waste processing/disposal schemes. However, landfilling is associated with the inevitable formation of heavily polluted leachate generated as a result of biochemical processes and rainwater percolation within landfills and if not properly treated, leachate can threaten the receiving environment (Renou et al., 2008; Kurniawan et al., 2010; El-Fadel et al., 1997). For this context, various biological and physical/chemical technologies have been developed for its treatment. Biological technologies are often applied to treat the bulk of the biodegradable fraction in the leachate, while physical/chemical methods are usually adopted as pre/post treatment or to remove specific recalcitrant pollutants. The promulgation of stringent discharge standards to protect water resources has led to the development of combined biological and physical/chemical separation processes, with the membrane bioreactor (MBR) system increasingly being recognized as the process of choice for the treatment of high-strength wastewater characterized by high content of complex and recalcitrant compounds (Hashisho and El-Fadel 2016; Sutherland, 2010; Yang et al., 2006). The main advantages of MBRs include their efficient filtration that holds small particles (size < 0.1 μm) (Santos et al., 2011), ability to replace the second stage of conventional wastewater treatment (i.e. gravity settling), production of a better quality effluent, and reduction of reactor volume and footprint (Hashisho et al., 2016).

While the literature on the use of various membrane types (e.g. hollow fiber and flat sheet) in MBRs for the treatment of high strength industrial wastewater is relatively rich (Gao et al., 2013;

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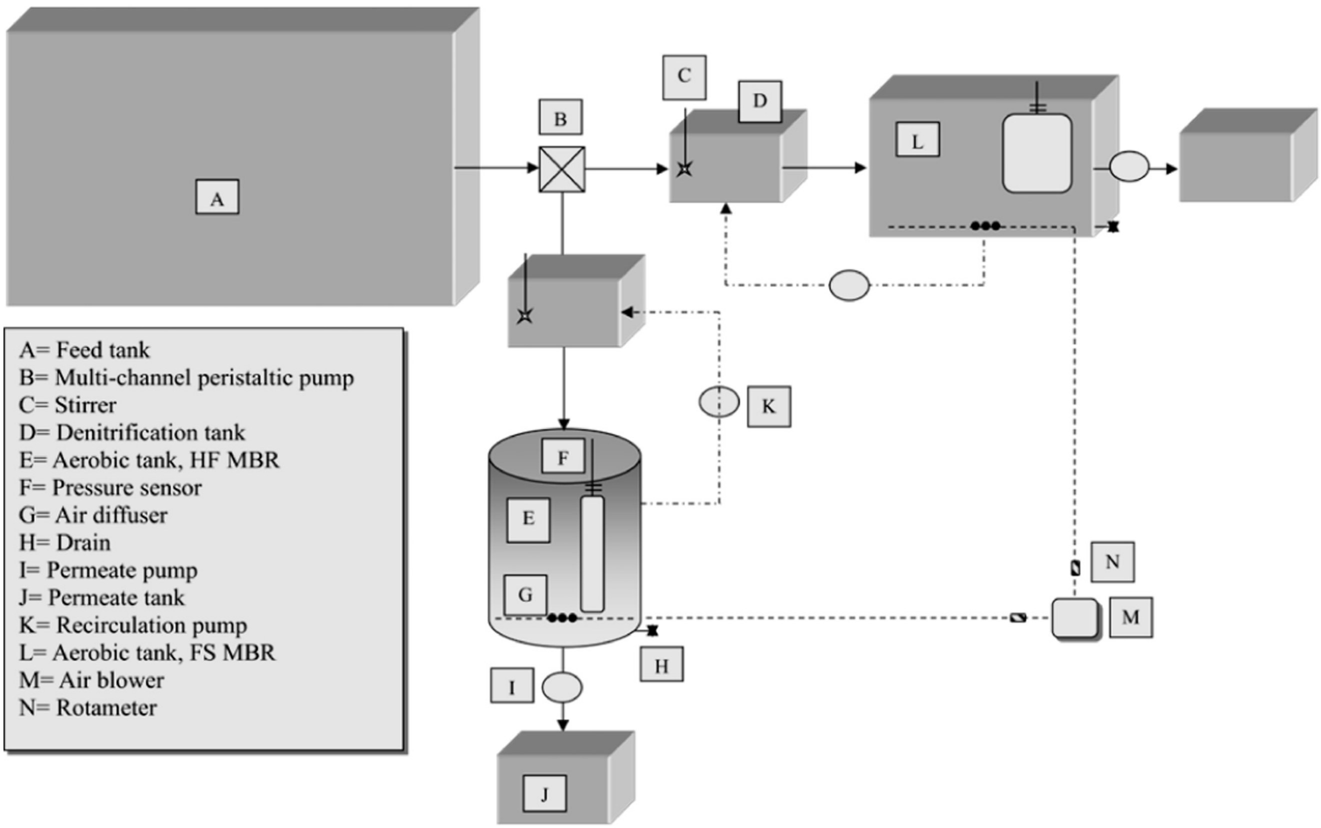

Fig. 1. Experimental setup.

Hai et al., 2005), studies examining the efficacy of various membrane types under varying solid retention time (SRT) for the treatment of high strength stabilized landfill leachate are limited (Hashisho et al., 2016; Remmas et al., 2016, 2017a, 2017b). In this context, the optimal operational SRT for MBRs remains debatable. Long SRTs are desirable for higher biomass retention, which lead to improved treatment efficiency and dominance of slow growing microorganisms that are able to consume macro-molecules such as polysaccharides, carbohydrates, and proteins (Ahmed et al., 2007; Masse et al., 2006). However, excessively long SRTs can lead to the accumulation of dead and inactive microorganisms, resulting in reduced sludge activity (Han et al., 2005; Huang et al., 2001) and low wasting frequency that can hinder phosphorus removal. In addition, while high SRTs can reduce extracellular polymeric substances (EPSs) and soluble microbial products (SMPs) concentrations in the mixed liquor by promoting starvation conditions in the MBR creating an enabling environment for reduced formation of EPS, excessively high SRTs (50, 70 and 100 d) have been reported to promote microbial lysis that generates EPSs or SMPs that can contribute to fouling (Han et al., 2005; Iorhemen et al., 2016). EPSs are known to interfere with the permeate flow across the membrane through the formation of aggregates of bacteria in biofilms and flocs, the development of barriers around bacteria, the retention of water, and embedment of bacteria in hydrated gel matrix (Le-Clech et al., 2006). SMPs, on the other hand, can block pores and form a gel structure on the membrane surface that can hinder the filtration process (Rosenberger et al., 2005). Accordingly, whilst high levels of mixed liquor suspended solids (MLSS) and SRTs were adopted in old MBR systems (e.g. up to 30 g/L, 100 days), lower and more controllable levels are being chosen for the newer systems (e.g. up to 16 g/L, 14 days (Jia et al., 2009) in order to decrease fouling propensity and cleaning frequency (Le-Clech et al., 2006).

In this study, common membrane modules, hollow fiber (HF), and flat sheet (FS),[1] were tested in a pre-denitrification MBR system under varying SRTs to assess their effectiveness in treating stabilized high strength landfill leachate and to define potential fouling rates under steady state conditions. During the process, several indicators[2] were monitored at various compartments (i.e. anoxic and oxic tanks) of the MBR systems. Concurrently, bacterial communities in the mixed liquor and on the membrane surfaces (biofilms) were characterized using 16S rRNA gene sequencing to identify linkages between systems' performance and microbial community composition.

2. Materials and methods

2.1. MBR construction and operation

The experimental setup (Fig. 1) consisted of two 10 L-Plexiglas anoxic tanks (D), stirrer mixers (C) to prevent settlement of solids, and two 50 L-Plexiglas oxic tanks (E, L), with one equipped with FS module (L) and the other with HF module (E). The FS Kubota 203 module consisted of a Chlorinated Polyethylene microfiltration membrane of 0.2 μm nominal pore size and a surface area of 0.1 m^2, while the HF ZW 10 module consisted of neutral hydrophilic ultrafiltration membrane with 0.03 μm nominal pore size and a surface area of 0.93 m^2 (Table 1). A blower (M), with a rotameter

[1] While HF offers the advantage of a high surface-area-to-volume ratio, due to its high packing density; combining compactness, simple and modular reactor design, and leachate treatment by MBRs have generally employed HF membrane modules with a fewer number adopting the FS membrane modules Cui et al. (2003); Le-Clech et al. (2006).

[2] Note that data on phosphorus removal achieved by MBR treating stabilized leachate is scarce, with limited to no data on removal achieved by FS MBRs Hashisho et al. (2016).

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