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Research article

Assessment of dynamic membrane filtration for biological treatment of old landfill leachate

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A B S T R A C T

This study investigated the behaviour of dynamic membrane (DM) filtration for the treatment of stabilised landfill leachate in a bench-scale pre-anoxic and aerobic submerged dynamic membrane bioreactor (DMBR). Four meshes with different openings (10, 52, 85 and 200 μm) were tested to support the development of DM. Differences were observed among the meshes in supporting the development of the cake layer constituting the DM. The treatment of landfill leachate had an impact on sludge characteristics resulting in deteriorated filtration performance of the DM. Effluent turbidity was often higher than 100 NTU for larger mesh pore size (85 and 200 μm). Low effluent turbidity was achieved with meshes with 10 and 52 μm (13 ± 2 and 26 ± 4 NTU, respectively) although at membrane fluxes lower than 10 L m^{-2} h^{-1}. The bioreactor exhibited a moderate organics removal of 50–60% and an ammonia oxidation between 80 and 90%. Incomplete nitrification was observed due to increased concentrations of free ammonia and free nitrous acid, with nitrite effluent concentrations up to 1062 mgNO_2^--N L^{-1}. Due to the large presence of refractory organic matter in landfill leachate, denitrification was limited resulting in a total nitrogen removal of approximately 20%.

1. Introduction

Sanitary landfill has been acknowledged as the most economically viable ultimate disposal option for municipal solid waste in most parts of the World, despite being placed at the bottom of waste management hierarchy (Fudala-Ksiazek et al., 2016). A major concern arising during landfill operation is the production of leachate resulting from the infiltration of water through the landfill body and the decomposing of waste. If not properly managed, leachate could severely contaminate groundwater sources, raising concerns regarding the protection of natural environment and public health (Renou et al., 2008).

Landfill leachate (LFL) treatment is challenging due to the high levels of contaminants including organics, ammonia, inorganic substances, heavy metals and toxic hydrocarbons (aromatic and phenolic compounds) together with the variability in its quantity and quality in both space and time (Kulikowska and Klimiuk, 2008; Renou et al., 2008). Moreover, the worldwide application of recent environmental legislation is changing the waste management chain reducing the disposal to landfills and, as a result, changing the leachate production and composition (Fudala-Ksiazek et al., 2016).

Biological processes have been proved to be effective in treating young leachates whereas their efficacy reduces with the increase of leachate age due to a shortage of biodegradable matter and an increase of refractory organics (Brennan et al., 2017; Mohammad-pajooh et al., 2017; Renou et al., 2008; Oloibi et al., 2017).

Membrane bioreactor (MBR), which consists in the integration of microfiltration or ultrafiltration (MF/UF) membranes with biological reactors, has gained much appreciation over the last decade and has been perceived as an advanced treatment process considering its excellent effluent quality and flexible operation (Judd, 2011). Studies on leachate treatment have demonstrated that MBRs are very effective under a wide range of loading conditions as

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compared to conventional biological treatment systems, particularly in treating LFL from old landfills (Alvarez-Vazquez et al., 2004; Hashisho and El-Fadel, 2016). However, the application of high loading conditions, long hydraulic retention time (HRT) and solids retention time (SRT) and the high concentrations of contaminants can increase membrane fouling (Ahmed and Lan, 2012). In addition, excessive amount of humic and fulvic acids usually present in LFL have shown to speed up membrane fouling (Sutzkover-Gutman et al., 2010). In a recent review on MBR application treating LFL, Hashisho and El-Fadel (2016) concluded that membrane fouling was the main bottleneck in the widespread application of MBR in leachate treatment due to its high fouling potential especially while treating stabilised LFL.

In this regard, dynamic membranes (DMs) could represent an innovative approach by purposefully exploiting fouling as a mean for solid liquid separation (Alibardi et al., 2014, 2016; Saleem et al., 2016; Xiong et al., 2016; Zhang et al., 2010). DM is defined as a self-forming and regenerative fouling surface that is formed by the deposition of suspended solids, colloids and microbial cell particles over a coarse underlying support material (Ersahin et al., 2012; Li et al., 2011; Liu et al., 2009).

Most of the studies on DM have been carried out on synthetic or real municipal wastewater under aerobic or anaerobic conditions and for anaerobic sludge digestion (Alibardi et al., 2014, 2016; Saleem et al., 2016; Ersahin et al., 2016; Jeison et al., 2008; Li et al., 2011; Liu et al., 2009; Kiso et al., 2000; Hu et al., 2016; Xiong et al., 2016; Zhang et al., 2010). Xie et al. (2014) studied the performances of an anaerobic dynamic MBR for the treatment of leachate by using a 40 μm mesh as support material. Although these authors achieved solids retentions of the DM that were not comparable to those from MF/UF membranes, they reported a better effluent quality than conventional anaerobic treatment systems. To the best knowledge of the authors, no studies have yet evaluated the optimisation of organic matter and nitrogen removal for biological LFL treatment by using DMs. Similarly, the effect of the use of meshes with different pore sizes on the filtration performances of DMs treating LFL is also lacking.

This study aimed at evaluating the application of DMs in anoxic-aerobic process for the treatment of LFL from an old landfill. In particular, the effect of the use of different mesh sizes on the development of the DM was evaluated. The behaviour of developed DM was studied in conjunction with the effect of change in feed characteristics and operating conditions.

2. Materials and methods

2.1. Experimental setup

The study was conducted using a laboratory-scale, continuously mixed, anoxic-aerobic system (Fig. 1a). The experimental setup consisted of a pre-anoxic tank with a working volume of 2.8 L connected to an aerobic tank with a working volume of 7.5 L. The tanks were made up of 5 mm thick Plexiglas cylinders. The internal diameter was 24 cm and 18 cm for aerobic and anoxic tanks, respectively, while depth was 30 cm for both tanks.

The filtration modules were constituted by a nylon mesh wounded over a cylindrical frame. The frame was a plastic body having an external diameter of 15 mm and a length of 70 mm with uniformly distributed openings of 5 mm × 3 mm. The total surface area of the filtration module was 33 cm^2 and approximately 61% (ca. 20 cm^2) was the effective filtration area of each mesh. Three filtration modules were continuously immersed in the aerobic vessel and operated in parallel, resulting in a total effective filtration area of 60 cm^2. Filtration flux were controlled through a three-line peristaltic pump (Watson Marlow SCI 400) which was connected to the three modules.

Four different meshes with pore sizes of 10, 52, 85 and 200 μm were tested (Table 1). Meshes with porosities of 10, 85 and 200 μm were initially evaluated; however, due to changes in filtration behaviour of the sludge of the bioreactor, after 105 days of continuous operation the mesh with openings of 200 μm was replaced with a new one of 52 μm pore size.

The study was performed at ambient temperature (21 ± 1 °C). Aeration of the aerobic tank was provided by a small air pump and diffusers. The air flow was controlled by using an air flowmeter (ColeParmer 1-800-323-4340). Leachate was fed to the anoxic tank through a peristaltic pump (Watson Marlow SCI 400) connected to a level sensor. Sludge recirculation flow was approximately four to five times the influent flow and was provided by means of a peristaltic pump (Watson Marlow SCI 400). The two bioreactors were

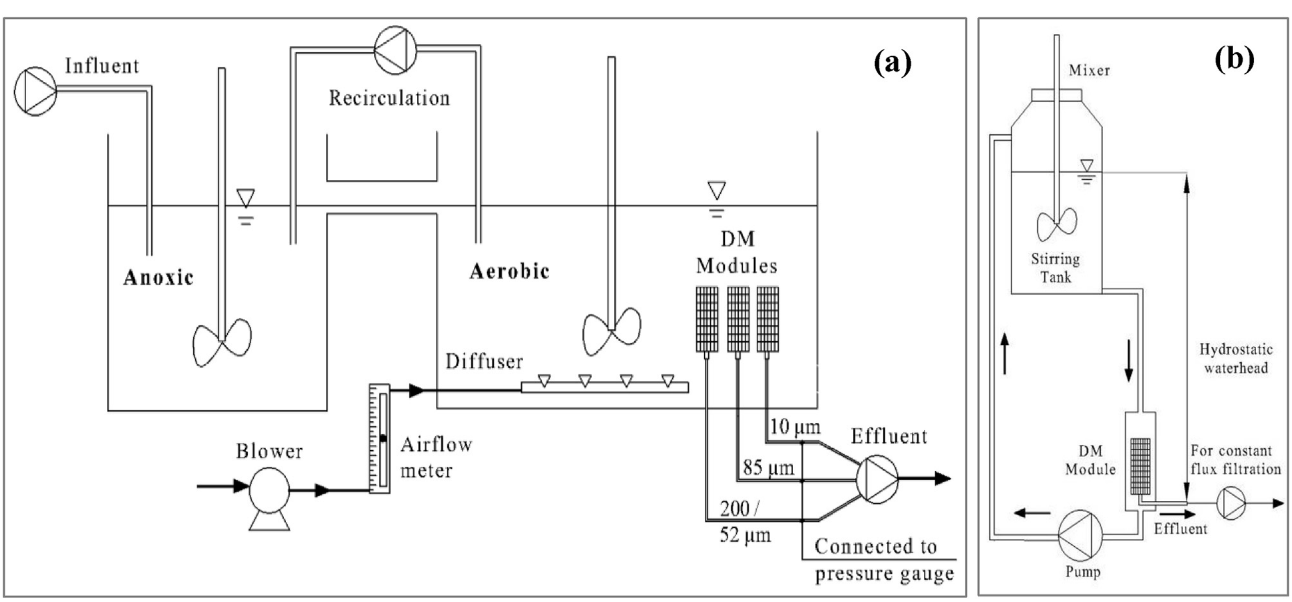

Fig. 1. Schematic diagrams (a) experimental setup and (b) short-term filtration test set-up.