Reducing the disturbances of the volumetric loading rates by applying an electrical direct current field: Another advantage of the submerged membrane electro-bioreactor

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Abstract

A novel submerged membrane electro-bioreactor (SMEBR) was investigated to improve the membrane filterability and reduce the disturbances of the volumetric loading rates by applying an electrical direct current (DC) field. The strategy of this study was based on operating the SMEBR for 53 days at a constant transmembrane pressure. For the comparison purposes, the SMEBR was operated in two sequential stages. In stage I, SMEBR was operated for 26 days without applying a DC field which produced a continuous variation in the hydraulic retention time (HRT) (the range was between 1.2 and 24 days) while in stage II, the variations in HRT decreased to be within the range of 1.2 to 5 days when intermittent DC (1 V/cm, 15 min ON/ 45 min OFF) was applied on the mixed liquor solution. The output results demonstrated that the SMEBR system can deal with sudden shocks in volumetric loading rates and the fluctuation in the removal efficiencies reduced significantly after applying a DC field.

Introduction

Membrane bioreactor (MBR) technology has exhibited promise as a very attractive method for wastewater treatment specifically the submerged membrane bioreactor (SMBR) configuration (Bani-Melhem and Smith, 2012). However, the operational efficiency of SMBR processes is still inhibited by the membrane fouling problem (Le-Clech et al. 2006). Various methods have been applied to reduce membrane fouling in SMBR technology. Among the different approaches cited in the literature, improving the characteristics of the activated sludge in the bioreactor by applying direct current (DC) field on the activated sludge has been shown as a promising and novel approach (Bani-Melhem, 2008; Bani-Melhem and Elektorowicz, 2010; Bani-Melhem and Elektorowicz, 2010).

Recently a new technology was developed at Concordia University (Montreal-Canada) called Submerged Membrane Electro-Bioreactor or SMEBR (US Patent, 2010, Bani-Melhem and Elektorowicz, 2010). The new technology was designed based on applying a DC field between immersed circular electrodes around immersed membrane filtration module. The significant benefits of designing the SMEBR system are: smaller footprint; no chemicals are required for coagulation; reducing the operating costs by reducing the requirements of aeration in conventional SMBR systems; and improving sludge dewatering conditions.

The original design of the SMEBR, including the design constraints and criteria, was described in details in previous article (Bani-Melhem and Elektorowicz, 2010).In another article, Bani-Melhem and Elektorowicz (2011) reported the results of the performance of the SMEBR system for improving the quality of the treated wastewater and reducing the membrane fouling. In this study, the application of the SMEBR for reducing the impact of the disturbances in the volumetric loading rates by applying intermittent electrical direct current (DC) field will be presented.

Material and Methods

Figure 1 shows a schematic diagram of the experimental setup used in this study. The setup consisted of an electro-bioreactor worked with volume of 13.4 L. Submerged hollow fibber membrane module ZeeWeed-1 (GE/Zenon Membrane Solutions, Canada) was fixed vertically in the centre of the electro-bioreactor. Cylindrical anode and cathode were made of iron mesh were used and fixed around the membrane module with an appropriate distances (Bani-Melhem and Elektrowizc, 2010). Therefore, the design of the SMEBR system consists of two zones being in a contact (Fig. 1): Zone I (electro-bioreactor) extends from the external wall of the reactor to the cathode and Zone II is located between the cathode and the membrane module. Generally, Zone I is dominated by the processes of biodegradation and electro-coagulation while Zone II is responsible for further biodegradation and membrane filtration.

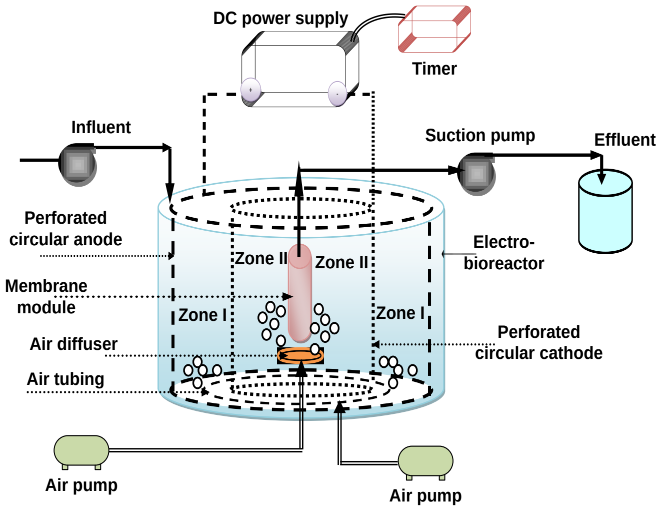

Figure 1- Experimental Setup of the SMEBR system

The strategy of this study was based on operating the SMEBR at a constant transmembrane pressure (TMP) to force the hydraulic retention time (HRT) varies with operating time to get different volumetric loading rates. For the comparison purposes, the SMEBR was operated in two sequential stages. In Stage I, the SMEBR was operated for 26 days without applying a DC field while Stage II lasted for 27 and an intermittent DC (1 V/cm, 15 min ON/ 45 min OFF) was applied on the mixed liquor solution.

Results and Conclusions

From operational point of view, the change in the HRT (reactor volume/ effluent flow rate) during the operation of the SMEBR system is considered a direct indication of the performance of the SMEBR system to reach the steady state. Figure 2 demonstrates a rapid increase in the HRT during Stage I due to the rapid decline of permeate flux, reflecting unsteady state conditions.

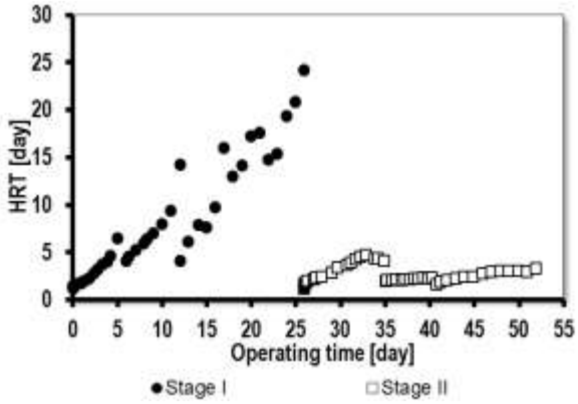

Figure 2- Changes of the hydraulic retention time during the operation of SMEBR system.

The HRT increased from 1.2 days at the beginning of the operation, and reached 6.5 days after five days and 24 days at the end of operation in Stage I. However, the fluctuation in the HRT diminished in Stage II as a result of a decrease in the fouling phenomenon. The HRT did not exceed 5 days during the operation period of Stage II. This means that the SMEBR system achieved steady state conditions when the fouling rate decreased, while considering that no backwashing was done to reach this situation.

The continuous variations in the HRT affect the volumetric loading rates to the SMEBR system which led to a significant fluctuation in the removal efficiencies as shown in Fig. 3. However, the variations in the volumetric loading rates were reduced in Stage II as the systems went to operate at steady state conditions. These trends had impact on the biological removal efficiencies. The better performance in membrane permeability during the operation of Stage II associated with an improvement in regards to effluent quality (Table 1).

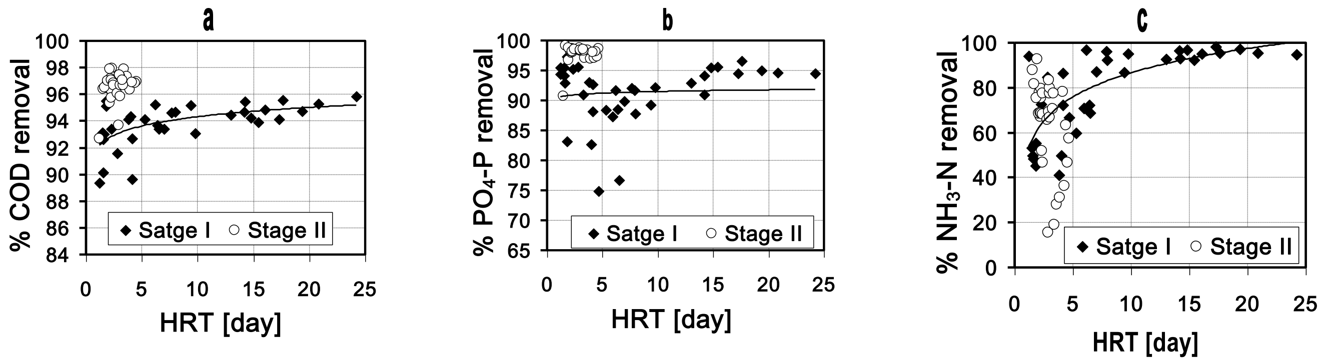

Figure 3 - Changes of volumetric load rates of (a) COD, (b) PO_4-P and (c) NH_3-N in SMEBR system

Table 1 Characteristics of the influent and the pollutants removal efficiencies of the SMEBR system

Water quality Index	Influent (mg/L)	Effluent (mg/L)	
		Stage I	Stage II
		% Removal	% Removal
COD	334 ± 23	88 %-96%	92%- 98.5%
NH_3-N	30.8 ± 2.1	35%-100%	10%-85%
PO_4-P	27.2 ± 1.9	75%-93%	> 98%

Figure 3 shows that the removal efficiencies of COD, NH_3-N and PO_4-P are affected by the fluctuation of the HRT during Stage I (where no DC was applied). I general, the removal efficiencies increased with increasing in the HRT. Figure 3 shows that the removal efficiencies were less dependent on the HRT (Stage II) when the variation in the HRT diminished. The reasonable explanation for that might be due to electrocoagulation process itself, which occurred in the electro-bioreactor; this phenomenon made a continuous production of flocs, and able to deal with the sudden increase in the volumetric loading rates. The benefit of designing SMEBR system was most clearly observed in the reduction of phosphate (PO_4^{3-}) up to 98 % which cannot be achievable in conventional SMBR systems.

In conclusion, the designed SMEBR system can deal with sudden shocks in volumetric loading rates, which is considered another advantage of the designed SMEBR system. The SMEBR is a hybrid wastewater treatment method which will initiate investigations on a more sustainable design system.

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