Development of Self-forming Dynamic Membrane Bioreactors (SFDMBRs) for Energy-efficient Compact Sewage Treatment

Dao GUAN, Ji DAI, Bai Peng, and G. H. Chen*
Department of Civil and Environmental Engineering, Hong Kong University of Science & Technology, Clear Water Bay, Hong Kong, China (ceghchen@ust.hk)

ABSTRACT

Membrane Bioreactor (MBR) has been developed and applied as a compact treatment technology. However, application is still hindered by relatively high capital and maintenance costs due to its low permeate flux rate and frequent membrane fouling control operation. As an alternative, low-cost filtration materials have been applied to develop Self-forming Dynamic membrane bioreactors (SFDMBRs). This paper shares the development of this new technology at the Hong Kong University of Science and Technology. A pilot scale trial of 10 m^3/day was first conducted with saline sewage without encountering membrane fouling for up to 270 days in 2009-2010. A larger scale trial was further conducted with industrial and domestic mixed saline wastewater in 2012-2013. Dynamic membrane formation and fouling control optimization has then been investigated in scale down of the SFDMBRs system to improve the effluent quality towards reuse/recycle level, during which major influencing factors including aeration strength, permeate flux, backwash frequency, pore size of the supporting material, membrane module structure, sludge properties and etc. were examined carefully. The optimized module achieves better effluent quality with turbidity below 2 NTU stably after 10 min start-up.

1. INTRODUCTION

Conventional MBRs build on micro-filtration (MF) and ultra-filtration (UF) [1]. It produces excellent effluent quality in small footprint, suitable for space saving and/or effluent reuse [2]. However, high operation and maintenance (O&M) cost limits its applicability in domestic wastewater treatment [3], mainly arising from energy-intensive membrane fouling control. As an alternative, Self-forming Dynamic Membrane Bioreactors (SFDMBRs) has recently been proposed. Instead of MF/UF membrane, it uses low-cost filtering materials such as woven [4,5] or non-woven fabric [6,7] on which biofilm (bio-cake) with sludge flocs forms automatically during filtration while during backwash it is removed. Such self-forming dynamic biofilm performs as a micron-level liquid-solid separator. It does not require any chemical cleaning except physical cleaning, i.e. periodic backwash. Hence, less membrane fouling and high permeate flux enable SFDMBRs compete against conventional MBRs in terms of cost [8], if effluent reuse and recycling is not considered. In last decade, a high-flux SFDMBRs process using nylon woven mesh has been developed at the Hong Kong University of Science & Technology (HKUST) [8, 9]. Upgrade of this compact treatment technology towards effluent reuse and recycling is being investigated at lab. This paper summarizes the main results from two pilot trials and on-going lab work.

2. MATERIALS AND METHODS

An anoxic - oxic (A/O) process was adopted in both pilot plants as well as in the lab system, as shown in Fig. 1. The first pilot trial was conducted at HKUST treating campus sewage, while the second pilot trial was conducted at Kwai Chung Industrial Wastewater Sewage Pumping Station treating a mixture of wastewaters from industrial and domestic sources. The operational parameters are shown in Table 1.

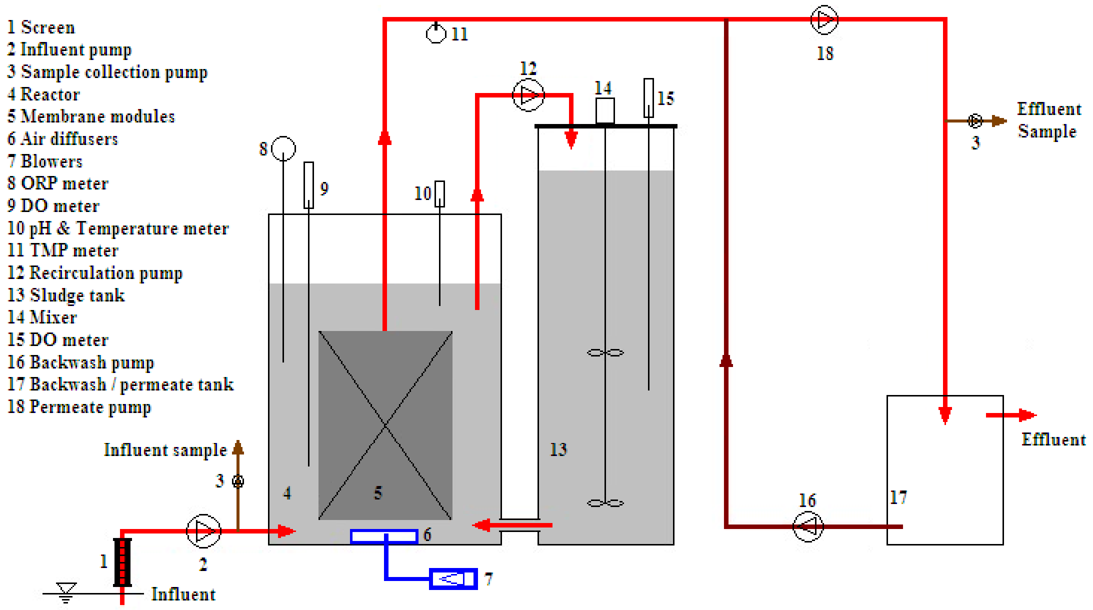


Figure 1: Diagram of the SFDMBRs process [8]

Table 1 Operation conditions in the pilot trials and lab system

	Hydraulic Capacity (m^3/day)	Flux (m^3/m^2·day)	TMP (bar)	HRT (hours)	Membrane pore size (μm)	Recycle rate from oxic to anoxic tank
HKUST pilot	7	4	< 0.2	4	54	2.0
Kwai Chung pilot	10	11.76	< 0.3	4	54	1.0 (Phase I), 2.0 (Phase II)
Lab study	0.18	2	< 0.4	4	38, 54, 74	2.0

The HKUST pilot plant was operated for more than 360 days under a permeate flux rate of 4 m^3/day with membrane backwash once in every 24-48 hrs using 1% of the effluent, while the Kwai Chung pilot trial was conducted with a flux rate of 20 m^3/day for 165 days. The lab study was conducted with synthetic wastewater in order to adjust the particle size of mixed liquor suspended solids (MLSS) so that correlation of sludge particle size with mesh pore size and their effect on the effluent quality can be studied effectively. According to the sludge particle size distribution in the lab system, three different mesh sizes: 38, 54, and 74 μm were tested.

3. RESULTS

3.1. Pilot trials

Figure 2 shows the performance of the HKUST pilot plant [9], which TSS, COD, ammonia, and TKN removal efficiencies reached 92, 90, 92, and 93%, respectively. Figure 3 shows the performance of the Kwai Chung pilot plant during two steady state operation phases. The TSS removal efficiency was relatively stable at >95%. The average effluent TSS reached 16.6 mg/L, despite of very high influent TSS (~970 mg/L, mostly inorganic matter), while average COD removal was 80.9%. Since the particle size in the influent was 30 μm on average, smaller than the mesh pore size, non-fouling membrane fouling period was greatly affected due to particle accumulation in the mesh pores.

a

b

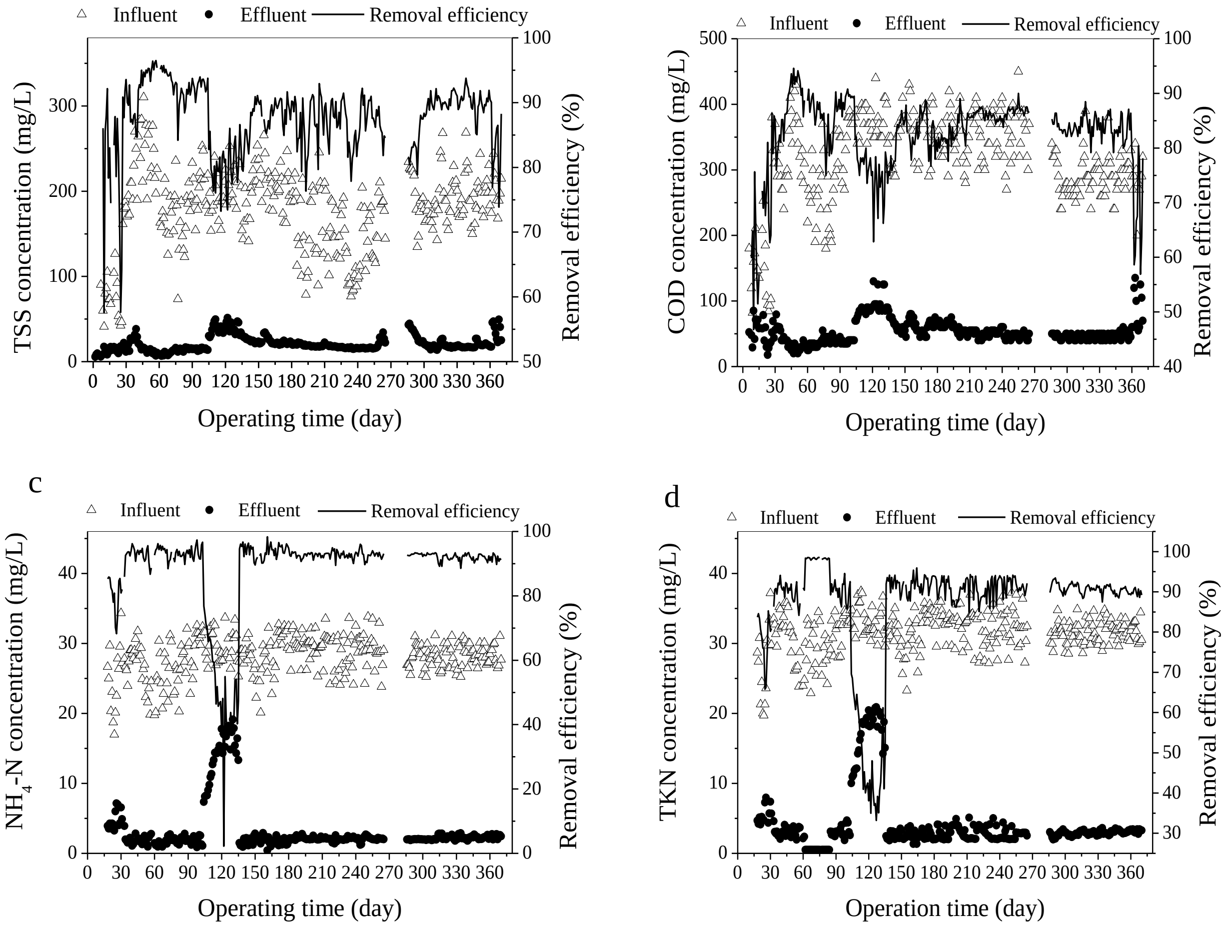
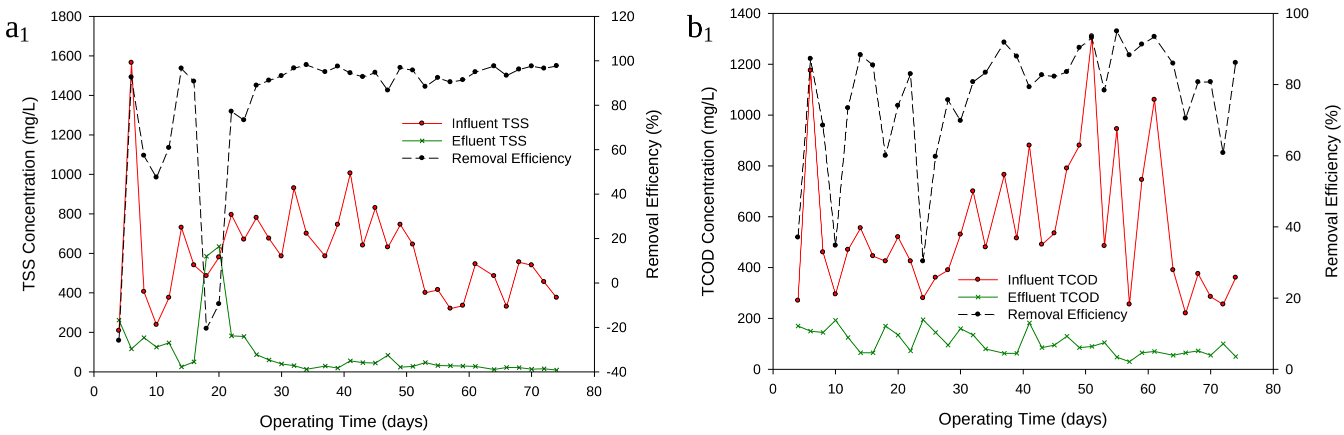


Figure 2: a) TSS, b) COD, c) ammonia, d) TKN in the influent and effluent, and their removal efficiencies of the HKUST pilot pilot [9].



a2

b2

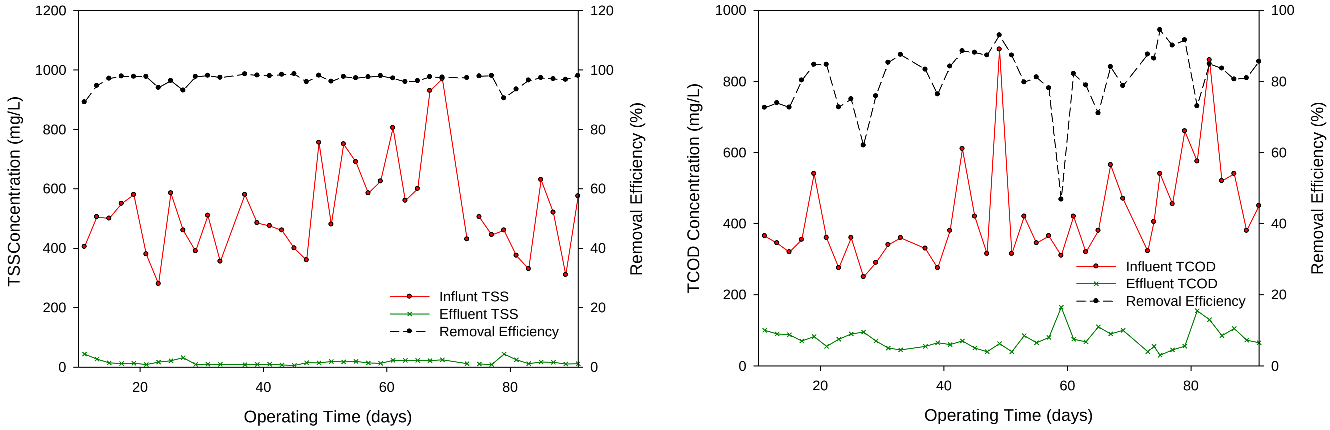


Figure 3: a) TSS and b) TCOD removal of the Kwai Chung pilot plant during operation phases 1 and 2

3.3. Lab study

Figure 4 shows the effluent SS concentration through the different pore size mesh modules and particle size distributions in corresponding with mixed liquor and effluent. Clearly the 38 μm mesh module could perform the best in terms of effluent quality and maintained effluent turbidity below 2 NTU stably after 10 min start-up (data not shown).

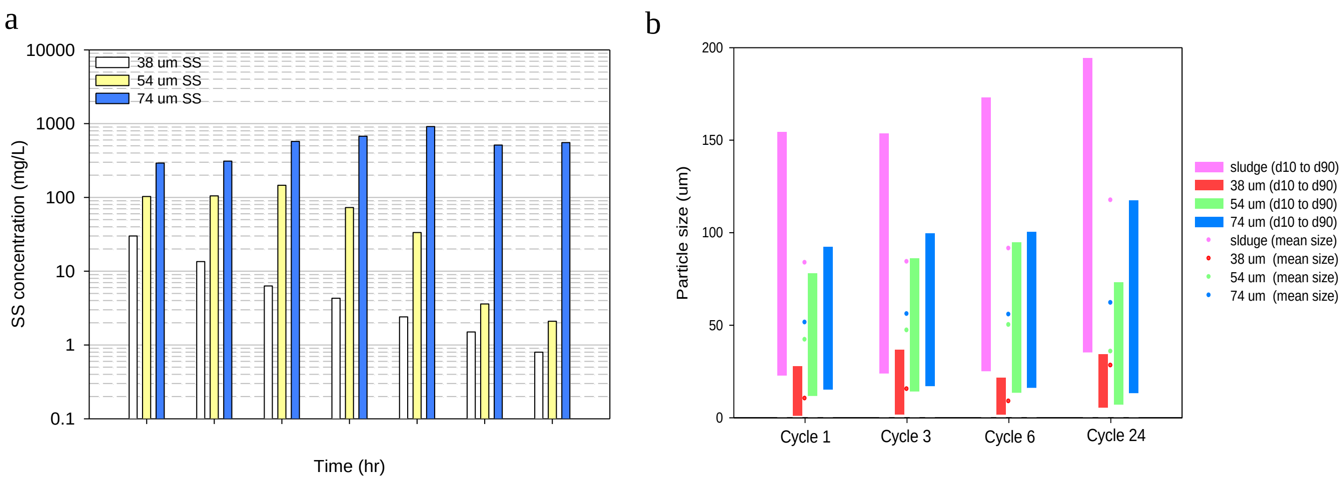


Figure 4: a) Effluent SS concentration and b) particle size distribution in the mixed liquor and effluent.

3. SUMMARY

The SFDMBR technology developed at HKUST satisfies the secondary discharge standards and scale-down study is improving the effluent quality significantly.

Acknowledgement

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