Supporting Information

Performance of Alternating Current-enhanced Anaerobic Membrane Bioreactor: Membrane Fouling, Wastewater Treatment and CH_4 Production

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Supporting Information Content

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EXPERIMENTAL

1 Preparation of CHFMs

The carbon nanotubes hollow fiber membranes (CHFMs) used in this work were prepared based on wet-spinning technology. Specifically, carbon nanotubes (CNTs, Shenzhen Nanotech Port Co. Ltd., China) were firstly functionalized by HNO_3/H_2SO_4 (1:3, v/v) solution at 60 °C for 30 min with stirring. Then, the mixture was washed to pH around 7 by deionized water and recovered carbon nanotubes materials by filtration. The surface functionalization CNTs were dried by freeze drying method and then reserved at room temperature. Functionalization CNTs, polyvinyl butyral (PVB) and N,N-Dimethylformamide (DMF) were blended to form homogeneous spinning solution with the proportion of 1:0.5:10. Then homogeneous spinning solution was injected into water through a coaxial two capillary spinneret to obtain CNTs/PVB hollow fiber membranes. Subsequently, free-standing CHFMs were prepared by calcining CNTs/PVB hollow fiber membranes in a flow of nitrogen at 600 °C for 2 h.

2 Membrane performance tests

The main membrane properties, such as membrane pore size, morphology of membrane surface, hydrophilicity or hydrophobicity, and pure water permeate flux were analyzed in this work. Among them, membrane pore size was obtained by pore size tester (POROLUX^{TM}1000, POROMETER, Germany) with the total measurement range from 500 microns to 18 nm. Anhydrous ethanol was used as wetting liquid. Visual observation of membrane surface/pores morphology were from SEM images (FESEM, Hitachi S-8010). The SEM was operated at 5 kV on a microscope with 1.0

nm resolution. The samples were pretreated by spraying gold nano on the membranes for a good conductivity before observation. Hydrophilicity/hydrophobicity was measured by automatic contact angle meter (SL200B, Kono Industrial Co., Ltd., USA) with ultrapure water as the test liquid. The pure water permeate flux J ($L \cdot m^{-2} \cdot h^{-1} \cdot bar^{-1}$) was measured by collecting the permeate water (V) through the membrane and calculated using the following equation:

$$J = \frac{V}{A \cdot \Delta t} \quad (1)$$

where J is the permeation flux ($L \cdot m^{-2} \cdot h^{-1}$), V is the volume of the permeate (L), A is the membrane area (m^2) and Δt is the permeate collection interval (h).

3 EPS extraction

According to the methods in the reports of Sheng et al.,[1] the EPS from biomass was extracted by NaOH extraction method. Specifically, the activated sludge (1.0 g) was collected after centrifugation (10000 rpm, 5 min). Then 10 ml pure water and 0.06 ml formaldehyde solution (36.5%) were mixed into the weighted activated sludge. 1 h later, 10 ml NaOH solution (1 mol) was added into the mixture and saved for 3 h. The entire standing process was carried out at 4 ℃. Finally, the supernatant (namely EPS in biomass) after centrifugation (20000 G, 20 min) was collected and used for further analysis. The carbohydrate content was determined by the phenol-sulfuric acid method,[2] using glucose as a standard. The protein content was measured using the Bradford method[3], with bovine serum albumin as a standard.

4 Reactors setup and operating conditions

The strength of influent was 1000 mg/L from the 1st day to the 15th day, and 1500 mg/L from the 16th day to the 40th day. And the synthetic municipal wastewater with 500 mgCOD/L consists peptone 0.1g, yeast extract 0.01 g, NaCl 0.05 g, KH_2PO_4 0.0225 g, $NaHCO_3$ 0.075 g, $MgSO_4 \cdot 7H_2O$ 0.025 g, $CaCl_2$ 0.025 g, glucose ($C_6H_{12}O_2$) 0.47 g, trace elements 2 mL. Among them, the trace element consists EDTA-2Na 9.38 g, $CaCl_2 \cdot 6H_2O$ 0.15 g, $CuSO_4 \cdot 5H_2O$ 0.16 g, $NiCl_2 \cdot 6H_2O$ 0.12 g, H_3BO_4 0.009 g, $ZnSO_4 \cdot 7H_2O$ 0.27 g, $MnCl_2 \cdot 4H_2O$ 0.62 g, $NaMoO_4 \cdot 2H_2O$ 0.14 g, $NaWO_4 \cdot 2H_2O$ 0.05g and the concentration does not change with the intensity of influent.

RESULTS AND DISCUSSION

Table S1. Characteristics of single CHFM

Parameters	**Value (CHFM)**
Outer/inner diameter	~1.05 mm/0.55 mm
Pore size	~430 nm
Porosity	~80 %
Pure water flux	~1730 L/(bar·m^2·h)
Contact angle	Average 73°

Table S2. The average MLVSS (g/L) variation of A-AnMBR, C-AnMBR and AC-AnMBR

Day	A-AnMBR	C-AnMBR	AC-AnMBR
1	3.250 g	3.300 g	3.400 g
7	3.380 g	3.450 g	3.590 g
21	3.966 g	4.150 g	3.990 g
35	4.689 g	4.734 g	4.766 g
40	4.869 g	4.855 g	4.921 g

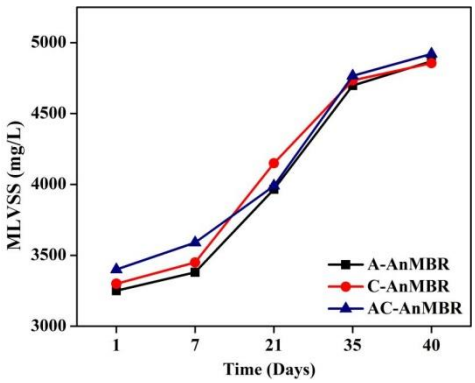

Table S3. The electric energy calculation

Stage	A-AnMBR	C-AnMBR	AC-AnMBR
Permeate (m^3 /d)	2.4×10^{-3}	2.4×10^{-3}	2.4×10^{-3}
Applied bias (V)	1.0	1.2	1.0/1.2
Current (I)	1.06×10^{-3}	1.27×10^{-3}	1.06×10^{-3}/4.8×10^{-3}
Electric energy (kJ/d)	1.83	2.63	2.63/1.83
Electric energy (kWh per unit m^3 of permeate)	0.21	0.3	0.26

In this manuscript, the energy consumption used for electrochemical reaction was calculated by measuring the electric current at -1.2 V/+1.0 V on the electrochemical workstation. Herein, the I value was 0.00127A (-1.2 V)/0.00106 (+1.0 V), t was 1.2 V and 24 h, respectively. The length used for electrochemical workstation was 5 cm and the total length in bioreactor was about 100 cm. Therefore, the energy added to the circuit by the power source was 20 times higher than the equation:

$$W = UIt, \quad (2)$$

On the basis of the above-mentioned equation, energy consumption was calculated about 1.83 kJ in A-AnMBR, 2.63 kJ in C-AnMBR and 2.23 kJ in AC-AnMBR within

24 h in our system. The permeate of the AnMBR at HRT of 10 h was 2.4×10^{-3} m^3 /d. Therefore, the final energy consumptions were 0.21, 0.3 and 0.26 kWh per unit m^3 of permeate in A-AnMBR, C-AnMBR and AC-AnMBR, respectively.

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