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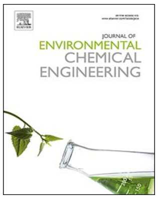

The influence of hydraulic retention time on cake layer specifications in the membrane bioreactor: Experimental and artificial neural network modeling

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ABSTRACT

The fouling control mechanisms were elucidated in the membrane bioreactor (MBR) by investigating the cake layer specifications in the different hydraulic retention times (HRTs). In this study, petrochemical wastewater was used. The sludge particle size distribution (PSD), excitation-emission matrix (EEM) fluorescence spectra, compressibility cake layer, Fourier transform infrared spectroscopy (FTIR) profile and extracellular polymeric substance (EPS) were measured to determine cake layer characteristics. The results showed that the particle size in the cake layer decreased with reduction in HRT while EPS concentration and transmembrane pressure (TMP) slope increased by time. The EEM florescence spectra of the cake layer showed the existence of two obvious protein-like substance peaks at the wavelength of Ex/Em of 290/355 and Ex/Em of 230–240/355 nm at different HRTs. Furthermore, a feed forward artificial neural network (ANN) was trained using back propagation algorithms for prediction effluent chemical oxygen demand (COD) and TMP. The best structure was a trainlm network with two layers including 17 and 2 neurons in the hidden layer and output layer, respectively. Sensitivity analysis showed that the most and the least sensitive parameters on TMP were mixed liquor suspended solid (MLSS) and time, respectively.

1. Introduction

In current years, the application of membrane bioreactor (MBR) systems instead of the activated sludge plant is becoming more common [1,2]. These systems compared with the conventional activated system (CAS) have many advantages. For example, MBRs provide the low sludge and the high removal efficiency for pollutants with low biodegrability [3,4]. However, MBRs do not have high performance in the nitrogen and phosphor removal due to the high dissolved oxygen in the activated sludge [5,6]. In addition, MBR systems have rapid decline of the permeation flux caused by the membrane fouling [7,8].

Membrane fouling is related to the sludge specifications, membrane characteristics and operating parameters such as hydraulic retention time (HRT) and sludge retention time (SRT) [9–11]. Furthermore, the larger flocs create higher porosity which causes less membrane fouling during the operation of MBRs [12]. It was revealed that the particles smaller than 50 μm could easily deposit on the membrane surface and decrease the membrane permeability [13]. Hence, having information about specifications of membrane foulants and fouling mechanisms in MBR system is vital [13–15].

Investigation of worldwide experience in the few recent years reveals that the number of professional and scientific papers which studied the effect of cake layer specifications on membrane fouling [16,17]. Up till now, there have been only few studies on petrochemical wastewater treatment by MBRs. Furthermore, no attempt has been made on the investigation of cake layer specification at the different HRTs. In this work, the effects of HRT on the membrane fouling and cake layer specifications were investigated while SRT was constant. Particle size distribution, extracellular polymeric substance (EPS) concentration, Fourier transform infrared spectroscopy (FTIR) profile, excitation-emission matrix (EEM) fluorescence spectra, and TMP were measured to evaluate the HRT possible effects on the cake layer characterization for treating petrochemical wastewater. Furthermore, the proper procedure and control of wastewater treatment systems, especially MBR, has become very imperative because it contains complex biochemical reactions [18,19]. In this work, artificial neural network (ANN) was used to model the performance of a MBR treating petrochemical wastewater at different HRTs in order to predict transmembrane pressure (TMP) and the chemical oxygen demand (COD) concentration to meet the effluent discharge standards.

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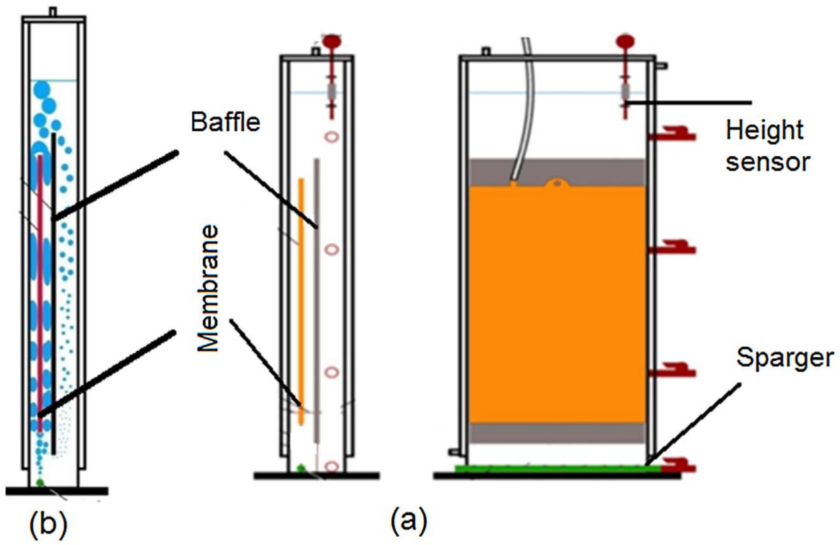

Fig. 1. (a) A lab scale membrane bioreactor with effective volume of 7 L (Dimensions of 60 × 22 × 6.5 cm) **(b)** Cleaning the membrane surface, using a poly methyl methacrylate plate as a baffle to keep the air bubbles near the membrane surface.

2. Materials and methods

2.1. Experimental setup

The effective volume for MBR at this setup was 7 L (Fig. 1a). The flat sheet membrane used in this work is produced by the SINAP Company. The effective area and pore size was 0.1 m^2 and 0.1 μm, respectively. To clean the membrane surface, a poly methyl methacrylate plate was used as a baffle to keep the air bubbles near the membrane surface. Injection of air bubbles near the membrane sheet can make appropriate tensions required to remove any visible cake layer adhering to the membrane surface. The distance of the baffle from the membrane was set to 7 mm (Fig. 1b). Further, a level measuring sensor was installed to control the volume of basin at 7 L.

The activated sludge, used as seed in the bioreactor was obtained from a petrochemical wastewater treatment plant. The sludge was adapted with synthetic feed for one month. For this idea, the initial COD concentration was set to around 200 mg/l and then increased to 1200 mg/l with a few step changes during one month. The synthetic wastewater applied in this work was similar to petrochemical industrial wastewater with COD concentration of 1200 mg/l [20]. In this study, membrane bioreactor was operated for a period of more than 4 month with HRT of 20, 15 and 10 h while SRT was set at 10 d. The operating conditions of the MBR system are described in Table 1. The analysis for sludge samples measured after reaching to steady state condition. This time was about 4 times of SRT. Further, each sludge sample was measured 3 times.

2.2. Analytical methods

2.2.1. FTIR analysis

A small amount of cake layer/biofilm on the membrane surface was collected by a sponge and then dissolved in 100 mL of ultra pure water. About 20 mL of these liquid were centrifuged for 10 min at 9000 rpm and the biomass obtained were placed in an incubator at 55 °C for 48 h to obtain dry foulants for FTIR profile (TENSOR 27, BRUKER) [21].

Table 1
Operating parameters for membrane bioreactor.

Parameter	dimension	From 0- 42th days	From 42th – 85th days	From 85- 125th days
HRT	hour	20	15	10
SRT	day	10	10	10
Effluent flux	$l/m^2.h$	3.18	4.24	6.36
OLR	$kg/m^3.d$	1.44	1.92	2.88
DO	mg/l	3.8 – 4.7	4–5	5.3–5.7

2.2.2. EEM fluorescence spectra

The luminescence spectrometry was used for EEM spectra (LS 55; PerkinElmer Company). In the measurements of fluorescence, a three dimensional spectra was obtained by collecting the wavelength of both excitation over a range of 200–400 nm and emission of 200–400 nm in step wise by 10 nm.

2.2.3. EPS analysis

The method described by Chang et al. [22] used for measurement of EPS. Protein fraction (EPSp) was measured by Bradford's method [23], whereas the related polysaccharide fraction (EPSc) was determined by phenol–sulfuric acid method [24].

2.2.4. Particle size distribution (PSD) analysis

The Fritsch “analysette 22” with a detection range of 0.01–1000 μm used for measurement of PSD.

2.2.5. General analysis

The effluent COD and mixed liquor suspended solid (MLSS) concentrations in the MBR were measured according to the standard methods [25].

2.3. Calculation of compressibility coefficient

The relationship between filtrate volume and time can be expressed by Eq. (1) and the compressibility coefficient of the cake layer calculated by Eq. (2) as follows [26]:

$$\frac{t}{V} = \frac{\mu.\ R_m}{A.\Delta P} + \frac{\mu.\ \alpha.C}{2A^2.\ \Delta P}V \tag{1}$$

$$\alpha = \alpha_0.\ \Delta P^n \tag{2}$$

where V is the volume of filtrate, t is the time, A is the filtration area, C is the suspended solids concentration, R_m is the membrane resistance, ΔP is the TMP, μ is the viscosity of permeate, n is the compressibility coefficient of the cake layer, α is the specific cake resistance, and α_0 is the specific cake constant.

2.4. Neural network model

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As