Desalination 260 (2010) 225–230

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

Air bubbling for alleviating membrane fouling of immersed hollow-fiber membrane for ultrafiltration of river water☆

Jia-yu Tian *, Yong-peng Xu, Zhong-lin Chen, Jun Nan, Gui-bai Li

State Key Laboratory of Urban Water Resource and Environment, School of Municipal and Environmental Engineering, Harbin Institute of Technology, Harbin 150090, China

ARTICLE INFO

Article history:
Received 22 November 2009
Received in revised form 4 April 2010
Accepted 9 April 2010
Available online 16 May 2010

Keywords:
Air bubbling
Immersed hollow-fiber membrane
Membrane fouling
River water
Ultrafiltration (UF)

ABSTRACT

In this paper, the influences of air bubbling mode, air flow rate, air bubble size and feed water quality on the membrane fouling of immersed hollow-fiber (HF) membrane for ultrafiltration of river water were investigated. The membrane was operated in the intermittent suction mode of 9 min on/1 min off. The results showed that continuous air bubbling was more effective for mitigating membrane fouling than intermittent bubbling (1 min on/9 min off in the study) at the same air flow rates of 1.0, 2.5, 5.0, and 7.5 m^3/m^2 h, respectively. Furthermore, an optimum air flow rate was observed for immersed HF membrane system when considering the alleviating effect on membrane fouling and energy consumption simultaneously, with the optimum value determined as 5.0 m^3/m^2 h in this investigation. It was also found that the smaller the air bubble was (4 dia of 3.5, 5.0, 6.5, and 8.0 mm were investigated), the more effective the air bubbling would be for mitigating the membrane fouling of immersed HF membrane. However, even if air bubbling was performed, eliminating membrane foulants from the feed water before ultrafiltration was still necessary for the reduction of membrane fouling.

1. Introduction

Hollow-fiber low-pressure (HFLP) membrane filtration technology in terms of microfiltration (MF) and ultrafiltration (UF) have been recognized as the key technology of the 21st century for both wastewater and drinking water treatment [1–5]. The membrane processes could offer many advantages over conventional treatment processes such as better quality of finished water, reduced footprint, and improved reliability. Due to the improved membrane materials and decreased costs, the HFLP membrane technology achieved an unprecedented development in recent years [6].

Both MF and UF are able to remove the majority of particles, colloids and microorganisms from drinking water source. Therefore, MF/UF alone is able to replace the whole conventional treatment chain (coagulation, sedimentation, filtration and disinfection), with the key function of removing turbidity and bacteria. As comparing with MF, UF could eliminate bacteria from source water completely, and even a large portion of viruses [7]. Thus, the application of UF technology is more relevant and promising in drinking water production.

In the past decade, immersed membrane process has gained more and more popularity not only in wastewater treatment [8] but also in drinking water purification [9], mainly due to the substantial reduction of energy consumption. However, membrane fouling still remains as a major obstacle for the wider application of immersed membrane filtration technology, which leads to the deterioration of water permeability and increase of operational costs [9,10]. Although chemical cleaning is effective for the elimination of membrane fouling, frequent chemical cleaning would cause the damage of membrane material and shorten the membrane module lifetime.

Several physical cleaning methods have been developed for the control of membrane fouling, such as air bubbling, backwashing, and sponge scrubbing [11]. Among which, air bubbling as one kind of fundamental strategies has been extensively applied in practice for mitigating membrane fouling of immersed membrane. Quite a few studies have been carried out to investigate the influence of aeration on membrane fouling in submerged membrane bioreactor for wastewater treatment [12–16]. However, few researches could be found on the fouling control by air bubbling in immersed HFLP membrane for drinking water treatment.

In this paper, the influence of air bubbling mode, air flow rate and air bubble size on the membrane fouling of immersed hollow-fiber membrane for ultrafiltration of river water is investigated. The results

☆ This manuscript was previously orally-presented at the 5th IWA Specialized Membrane Technology Conference for Water and Wastewater Treatment, Sep. 1–3 2009, Beijing, PR China.

* Corresponding author. Tel.: +86 451 86284512; fax: +86 451 86282100.
E-mail address: tjy800112@163.com (J. Tian).

0011-9164/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.desal.2010.04.026

might provide some references for the design and operation of immersed hollow-fiber membrane module for drinking water treatment.

2. Material and methods

2.1. Experimental set-up

The experimental set-up used in the experiments was schematically shown in Fig. 1. The raw water tank had an effective volume of 1.0 L, with an inner diameter of 6.5 cm. The UF membrane module was vertically immersed in the raw water tank. The permeate was suck from the tank by a peristaltic pump (BT100-1J, Longer Pump, China), and then recycled to the raw water tank. The trans-membrane pressure (TMP) was monitored by a pressure transducer (PTP708, Tuopo Electric, Foshan, China). A computer together with a data acquisition software was used to record the TMP data in real time. Air bubbling was provided below the membrane module in the raw water tank.

2.2. The hollow-fiber membrane module

The hollow-fiber UF membrane module used in the study was made in the laboratory. The membrane fibers were made of Polyvinylidene fluoride (PVDF), with an inner and outer diameter of 0.85 mm and 1.45 mm, respectively (provided by Suzhou Litree Ultrafiltration Membrane Technology Co. Ltd., China). According to the manufacturer, the mean pore size of the membrane was 0.01 μm. Each module contained 4 membrane fibers, with an effective length of 11.0 cm, corresponding to a membrane area of 0.002 m^2.

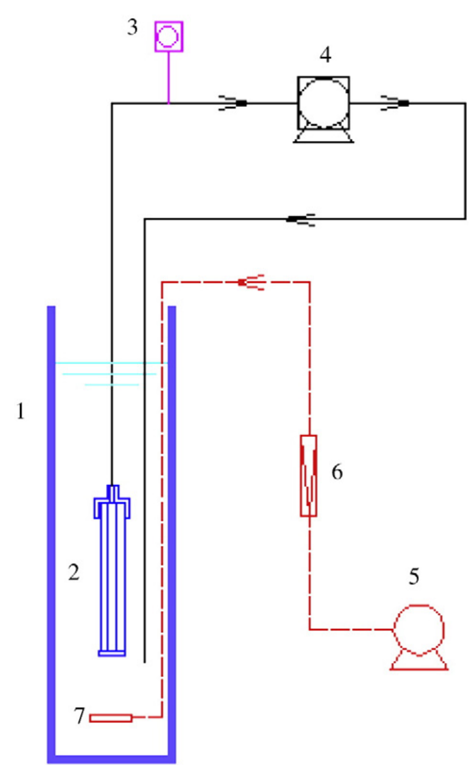

Fig. 1. Schematic diagram of the experimental set-up (1—raw water tank; 2—immersed UF membrane module; 3—pressure transducer; 4—peristaltic pump; 5—air pump; 6—air flow meter; and 7—air diffuser).

2.3. Operating conditions

In each run of the experiments, a new membrane module was employed. Before ultrafiltration of the raw water, the membrane module was first wetted with ethanol (analytical grade) for at least 60 min. Then, the membrane module was backwashed and thoroughly rinsed with deionized (DI) water, to eliminate the ethanol on the membrane. To accelerate the membrane fouling, a relatively high permeate flux of 60 L/m^2h was employed. Before each run of the experiments, 20 min of DI water filtration was first conducted; and the initial TMP of the membrane modules used in the study was determined as 18 ± 1 kPa.

The air flow was set at four rates: 1.0, 2.5, 5.0, and 7.5 m^3/m^2h (calculated based on the bottom area of the raw water tank). Four kinds of air diffusers were used to generate rising air bubbles with the diameters of 3.5 mm, 5.0 mm, 6.5 mm, and 8.0 mm, which were made of sands of different sizes. Because there was no boundary restriction for the air bubbles in the immersed membrane filtration system with conventional configurations, the air bubbles generated by the air diffusers were essentially spherical.

2.4. Analytical methods

Turbidity was measured by a turbidimeter (TURBO550, WTW, GERMANY). Total organic carbon (TOC) was determined with a TOC analyzer (TOC-VCPH, SHIMADZU, JAPAN). UV absorbance at 254 nm (UV_{254}) was analyzed using a spectrometer (UV754, CANY, China). Metal concentrations such as Ca, Mg, Fe, Mn, and Al were determined with an inductively coupled plasma-atomic emission spectroscopy (ICP-AES, Optima 5300DV, Perkin-Elmer, USA).

2.5. Characteristics of the raw water

Two kinds of feed water were investigated in the experiments, one was the river water taken from the Songhua river, a major drinking water source in Northeast of China; the other was the sand-filtration effluent taken from a drinking water plant with the river water as raw water, in which the conventional treatment processes of coagulation, sedimentation, sand-filtration and disinfection were employed. The experiments were carried out at the room temperature of 10.0 ± 0.2 °C. The water qualities of the two feed water were shown in Table 1.

It could be seen that the two feed waters contained a high content of organic matter (7.96 mg/L and 6.93 mg/L of DOC in the river water and sand-filtration effluent, respectively). On the other hand, the

Table 1
Water qualities of the two feed waters.

Parameters	River water		Sand-filtration effluent	
	Total	Dissolved	Total	Dissolved
Temperature (°C)	10.0 ± 0.2	–	9.9	–
pH	7.59 ± 0.21	–	7.55	–
Turbidity (NTU)	11.3 ± 1.06	–	1.68	–
Organic carbon (mg/L)	8.56 ± 0.61	7.96 ± 0.48	7.26	6.93
UV_{254} (1/cm)	–	0.105 ± 0.006	–	0.083
Al (mg/L)	0.44 ± 0.04	0.06 ± 0.05	0.17	0.03
Fe (mg/L)	0.43 ± 0.03	0.02 ± 0.02	0.06	0.00
Mn (mg/L)	0.05 ± 0.02	0.03 ± 0.01	0.05	0.04
Ca (mg/L)	27.68 ± 0.19	27.38 ± 0.12	27.44	26.98
Mg (mg/L)	7.18 ± 0.33	7.10 ± 0.37	7.15	7.04

1. Total concentration of water parameters was measured using the original water sample; while the dissolved fraction was determined after pre-filtration through the 0.45 μm membrane. 2. For river water, the measurement number $n = 5$; for sand-filtration effluent, $n = 1$.