

Application of membrane techniques to produce drinking water in China

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Abstract

Ultrafiltration of Binxian reservoir (near Harbin in China) water to produce drinking water was investigated in this study. Membrane flux declined with temperature coming down. Using coagulation before UF not only increases the permeate flux, but also retards the permeability decline. In comparison to the normal backwashing in which flow is reversed across the membrane once during each backwash cycle, two consecutive backwashing pulses during each cycle is an optimized operation. A chemical cleaning may be required to restore the initial performance of the membrane when the fouling occurs. As for Binxian reservoir water, 0.1% citric acid is a proper cleaning solution. Membrane filtration offers fewer coagulation agents needed and good quality of produced water.

Keywords: Ultrafiltration; Drinking water production; Backwash; Chemical cleaning; Permeate flux

1. Introduction

Membrane processes are gaining importance for water applications as a result of the advances in membrane technology and increasing requirements on water quality [1]. Low-pressure membrane technologies such as microfiltration (MF) and ultrafiltration (UF) are recognized as very attractive processes for producing drinking water.

Comparing to conventional treatment, membrane filtration offers several advantages such as fewer need of chemical agents, good quality of produced water, less production of sludge, compact process and easy automation [2,3]. In China, surface water is seriously polluted in some regions in which the advanced treatment facility should be constructed to produce safe drinking water.

In this study the UF hollow fiber membranes was used to treat reservoir water for drinking water production. The UF performance was evaluated

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in terms of flux and quality of treated water, and specific tests were conducted to investigate the behavior of permeate flux as a function of backwashing and chemical cleaning.

2. Materials and methods

2.1. Ultrafiltration process

Fig. 1 showed the schematic diagram of the UF facility used for the treatment of reservoir water. Two pumps were used for feeding and backwashing, respectively. Source water was pre-filtrated to 200 μm and injected in the raw water tank for ultrafiltration. Cross flow filtration inside the hollow fiber module divided feed into permeate and retentive which was recycled to the raw water tank.

The test apparatus had flow, pressure and temperature indicators and had the capabilities of automatic backwashing. Backwashing was performed by pumping the permeated water from the storage tank to the shell side of the hollow fiber membranes in the module. After washing the fouling from the membrane, the water was discharged from the recirculation loop.

2.2. Raw water characteristics

The Binxian reservoir water served as the source of surface water. The average characteristics were: pH 7.3, Turbidity 23 NTU and COD_{Mn} 5.3 mg/L.

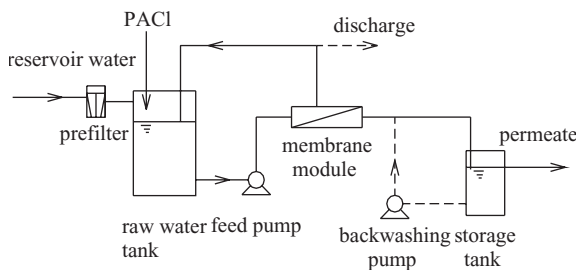


Fig. 1. Flow diagram of the apparatus for ultrafiltration and backwash.

Table 1
Membrane characteristics data

Parameter	UF membranes
Type	Hollow fiber
Material	PAN
Molecular weight cut off (Da)	50,000
Length (mm)	248
Hollow fiber internal diameter (mm)	0.9
Hollow fiber external diameter (mm)	1.5
Membrane surface area (m^2)	0.56
pH-range of operation	4–9
Temperature-range ($^{\circ}\text{C}$)	5–45

2.3. Membranes description

Ultrafiltration membranes made of polyacrylonitrile were used in the experiments. The nominal molecular weight cut off of these membranes as reported by the manufacture is 50,000 Dalton. Characteristics of the membranes were shown in Table 1.

3. Results and discussion

3.1. Effect of temperature on membrane flux

Because the system was operated continuously without heat exchanger, the measured flux was corrected to standard temperature of 20 $^{\circ}\text{C}$. Fig. 2 showed the permeate flux variation before

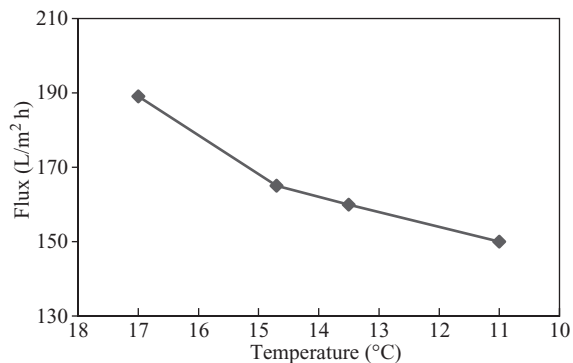


Fig. 2. Effect of temperature on membrane flux.

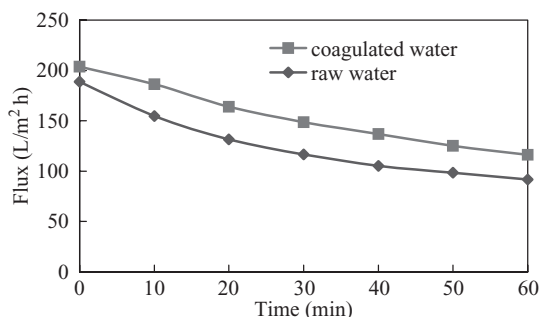


Fig. 3. Effect of coagulation on membrane flux.

temperature correction. With temperature decreases from 17°C to 11°C, membrane flux decreased from 190 L/m² h to 150 L/m² h. These results indicated that temperature had effects on membrane flux. When the temperature came down, the velocity of water molecule Brownian motion and its momentum and energy became lower, which resulted in the permeability decline.

3.2. Effect of coagulation on membrane flux

Effects of coagulation on membrane flux had been studied before, finding that the coagulation process improved membrane performance. Laine et al. [4] found a significant improvement in membrane flux in batch tests of reconstituted water after coagulation. Lahoussine-turcaud et al. [5] concluded that coagulation slow short-term reversible fouling. Fig. 3 compared the membrane flux variation of raw water to that of coagulated water. The raw water was 20 NTU with temperature 19°C and membrane filtration was performed

by transmembrane pressure (TMP) 0.1 MPa and with coagulant dosage of 5 mg/L PACl. When the feed was raw water without coagulation, membrane flux declined from 188 L/m² h to 91 L/m² h after 60 min, while for the coagulated water, membrane flux declined from 204 L/m² h to 116 L/m² h. The addition of coagulant not only increased the permeate flux, but also retarded the permeability decline. Coagulants act to neutralize the surface charge on stable colloids in solution, allowing them to collide, aggregate, and settle from solution. Table 2 compared the coagulant dosage added and treated water quality of direct ultrafiltration to that of Binxian Drinking Water Plant, where our test facility located, using conventional treatment: coagulation, sedimentation and sand filtration. Membrane filtration offered advantages of fewer chemical agents needed and good quality of produced water <0.2 NTU 100% times.

3.3. Backwash strategy

Periodic backwashing was widely used in MF and UF processes as a method to clean the membrane. Fig. 4 showed membrane flux change by backwashing in one of 490 min. By using a reverse TMP for very short periods of time, the permeate is forced through the membrane in the reverse direction and cause the filter cake or gel to expand, declog and eventually be carried away [6]. Shuji [7] indicated that backwashing pressure should be more than twice as high as filtration pressure in order to maintain a high and stable flux. Backwashing frequency does not seem to be

Table 2
Coagulant added and treated water quality

Raw water	Coagulant added (mg/L)		Treated water (NTU)	
	Drinking water plant	Direct ultrafiltration	Drinking water plant	Direct ultrafiltration
21 NTU	10	3	0.8	0.1
107 NTU	23	8	0.9	0.1
423 NTU	40	15	1.3	0.1

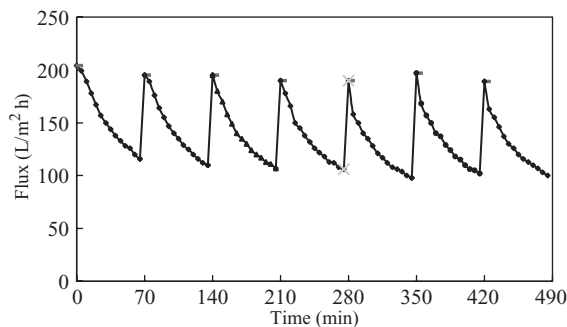


Fig. 4. Membrane flux variation by backwashing.

dependent upon the flux, when the UF is operated under the same water recovery condition. The effects of backwashing pressure on average flux for ultrafiltration membrane were shown in Fig. 5 by the plots of the flux vs. backwashing time. The filtration time in the test was 60 min. Backwashing at pressure 0.2 MPa and 0.22 MPa for 40 s can restore membrane flux to initial levels. Table 3 compared restoration efficiency of different backwashing methods. In comparison to the normal backwashing in which flow is reversed across the membrane once during each backwash cycle, two consecutive backwashing pulses during each cycle is an optimized operation. It is conducted by first backwashing with permeate for 25 s, then cross-flow filtration for

10 s, and backwashing for 15 s, which means we divided backwashing time 40 s to 25 s +15 s. As can be seen from Table 3, flux enhancement of 63% was obtained with optimized backwashing.

3.4. Chemical cleaning

Membrane fouling is generally not totally reversible by the hydraulic backwashing procedure. It represents a real brake to a wider application of UF for the treatment of most surface waters. If the fouling occurs, a chemical cleaning may be required to restore the initial performance of the membrane. Cleaning is a process where material is relieved of a substance, which is not an integral part of the material [8]. The success of cleaning procedures is usually assessed by the increase in the flux through fouled membrane. Fig. 6 compared flux restoration by different chemical agents. The fouled membranes were cleaned with chemical agents as follows: citric acid, sodium hydroxide and surfactants (sodium dodecyl sulfate). The concentrations of all cleaning solutions were 0.1%. Alkali was the weakest cleaning agents for the experimental condition. Surfactant had the moderate effect and acid provided the best cleaning efficiency. Cleaning agent diffuses the deposited cake layer on the membrane surface. A chemical reaction may occur

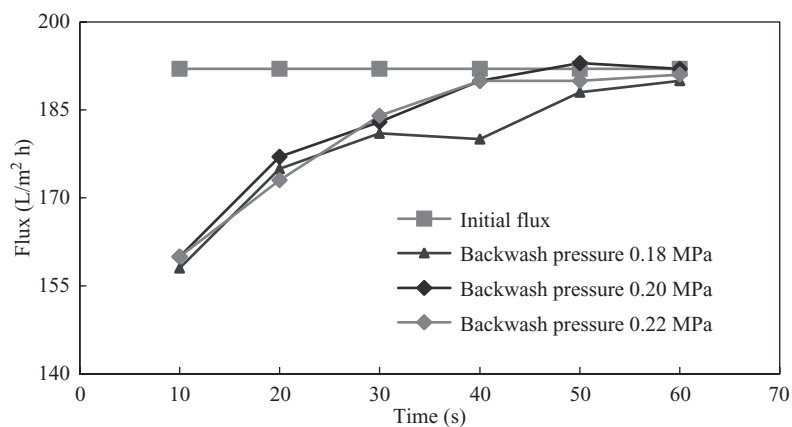


Fig. 5. Effect of different backwashing on membrane flux restoration.

Table 3
Efficiency of different backwashing methods

Backwashing methods	Flux before backwashing	Flux after backwashing	Restoration (%)
Normal backwashing 40 s	134	191	142
Two consecutive backwashing 40 s	132	203	153

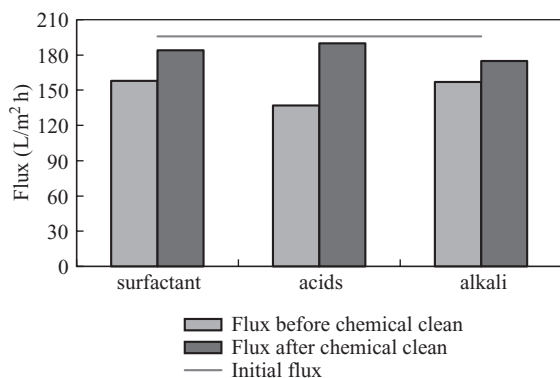


Fig. 6. Effect of cleaning agents on flux restoration.

between cleaning agent and substances on the cake layer, and this resulted in fouling materials removal from the membrane surface. It is desirable that various cleaning strategy for various source water with different feed quality. As for Binxian reservoir water, 0.1% citric acid is a proper cleaning solution.

4. Conclusion

Ultrafiltration of reservoir water can be used to produce drinking water. Membrane flux declined with temperature came down. Using coagulation before UF not only increases the permeate flux, but also retards the permeability decline. In comparison to the normal backwashing in which flow is reversed across the membrane once during each backwash cycle, two consecutive backwashing pulses during each cycle is an optimum

operation. A chemical cleaning may be required to restore the initial performance of the membrane when the fouling occurs. As for Binxian reservoir water, 0.1% citric acid is a proper cleaning solution. Membrane filtration offers lower coagulation agents needed and good quality of produced water.

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