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Cleaning of fouled ultrafiltration (UF) membrane by algae during reservoir water treatment

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Abstract

Ultrafiltration (UF) membrane fouling is often encountered in water treatment. Algae could be removed by UF membrane for its nominal pore size, and the algae cells deposited on the surface of UF membrane. The cells attach to the membrane, they start to release secretion and produce extracellular polymetric substances (EPS), which accumulate on the surface and cause the flux decline. This study examined the effects of hydraulic and chemical cleaning on fouled membrane by algae-rich reservoir water. Four kinds of hydraulic cleaning method were investigated, including forward flushing, backwashing, forward flushing followed by backwashing and backwashing followed by forward flushing. Backwashing followed by forward flushing was more effective for flux recovery, and 20 min duration were enough for the cleaning. To maximize flux recovery for the algae-fouled membrane, chemical cleaning was applied as enhanced cleaning strategies. NaOH, NaOCl, and citric acid were used for cleaning agents. The cleaning with the combination of NaOH (0.02 N) and NaOCl (100 mg/L) was effective than separate uses. And the cleaning duration was determined as 4 h.

Keywords: Cleaning; Ultrafiltration (UF); Algae; Fouling

1. Introduction

Ultrafiltration (UF) technology is a promising alternative technology to conventional water treatment and its application to drinking water treatment has been expanding in recent years [1–4]. UF membrane could remove algae completely [5]. However, transmembrane pressure seriously increases or flux decreases during algae bloom for UF operation [6]. And the algae cells release the extracellular polymetric substances (EPS), which lead to permeability decline and higher energy demands for maintaining a constant permeate flux [7]. The algae cells change their sizes, morphology,

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and EPS attached to their cells. The excretion of EPS depends on algal types. These EPS play an important role in UF fouling. Physical or chemical cleaning is needed when necessary [8,9]. Physical cleaning methods depend on mechanical forces to dislodge and remove foulants from the membrane surface. Physical methods include hydraulic cleaning, vibration, air sparge, and CO_2 back permeation. Hydraulic cleaning methods are often adopted in UF for drinking water treatment. Chemical cleaning that is more environmentally and membrane-friendly would be advantageous. And it depends on chemical reactions to weaken the cohesion forces between the foulants and the membrane surface. Chemical reactions involved in cleaning include hydrolysis, peptization, saponification, solubilization, dispersion, and chelation [10].

The fouling of UF membrane by algae-rich reservoir water is quite complex, which may be due to algae, bacteria, inorganic colloids, and EPS. Certain fouling problems can be solved by hydraulic flushing, and some like EPS fouling may only be solved by chemical cleaning. The surface of a fouled membrane can potentially be recovered by cleaning agents, in terms of hydrophobicity based on contact angle as well as surface charge based on zeta potential, resulting in changes of flux-decline trends after cleaning [9].

The purpose of the present study is an attempt to investigate the effects of cleaning strategies for flux recovery of an UF membrane fouled by algae-rich reservoir water.

2. Experimental

2.1. Feed water characteristics and membrane characteristics

Feed water used in this study was collected from an intake located at a reservoir (South China), the water quality of which is presented in Table 1. Reservoir water was algae-rich and the main algae categories were microcystis and chlorella.

Table 1
Feed water characteristics

Parameter	Range
Turbidity (NTU)	8.3–10.2
COD_{Mn} (mg/L)	2.9–3.5
Algae-count (10^4 cells/L)	710–1100
Fe (mg/L)	0.20–0.31
Mn (mg/L)	0.03–0.07

The membrane was a hollow-fiber UF membrane made of polysulfone (PS). The cut-off of the membrane was 25,000 Dalton. The effective membrane area was 0.22 m^2. Fig. 1 presents the experimental scheme of the process for algae-rich water treatment.

2.2. Experimental design

In this study, we applied preliminary design for optimization of fouled UF membrane cleaning. The membrane cleaning efficiencies were termed as flux recovery percent.

In hydraulic flushing, raw water was used for forward flushing and UF permeate was used for backwashing. Two kinds of combined flushing were investigated, forward flushing followed by backwashing and backwashing followed by forward flushing. Durations of hydraulic cleaning were investigated as 10, 20, and 30 min. And the operating pressures were selected as 120 kPa for forward flushing and 240 kPa for backwashing, respectively.

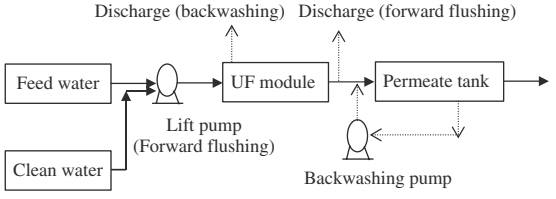

Fig. 1. Schematic diagram of the figure experiment.