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Tannin and polyacrylic acid polarity and structure influence on the performance of polyvinylchloride ultrafiltration membrane ☆

Xiaoyan Guo [a,*], Huaiqi Shao [b], Wanli Hu [a], Wei Gao [a], Xi Chen [a]

[a] Key Laboratory of Pollution Processes and Environmental Criteria (Nankai University), Ministry of Education, Tianjin Key Laboratory of Environmental Remediation and Pollution Control, College of Environmental Science and Engineering, Nankai University, 23 Hongda Street, TEDA, Tianjin, 300457, China
[b] Research Institute of Engineering Technology, CNPC, 40 Jintang Road, Tanggu, Tianjin, 300451, China

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ABSTRACT

Tannin and polyacrylic acid were selected to represent the hydrophobic and hydrophilic compounds with similar molecular weights to investigate their fouling characteristics on a polyvinylchloride ultrafiltration membrane and the cleaning efficiencies of the two compounds fouled membranes by three kinds of cleaning methods, i.e., backwashing, flushing&backwashing and 0.5% NaOH solution. The results obtained showed that their configuration optimized by PM3 method of quantum chemistry was significantly different, i.e., tannin was sphere-like, and polyacrylic acid was cylinder-like, though they had similar MW. The hydrophobic tannin, showed higher rejection and rapid permeate flux decline because it was prone to adsorption on membrane pore, resulting in partial flux recovery by hydraulic cleaning and complete recovery by NaOH cleaning. The hydrophilic polyacrylic acid rejection was lower, resulting from its penetrating through membrane pore, cylinder-like-configuration polyacrylic acid can twist in membrane pore passage so that the flux was not recovered by backwashing.

1. Introduction

Membrane filtration performances and fouling are dependent on several factors including membrane characteristics, operating conditions, and source water quality. Properties of the membrane include hydrophobicity, charge, surface roughness, and porosity [1,2]. Operating conditions of membrane system such as constant pressure and constant flux operation influence the membrane filtration performances [3]. The hydrodynamics of the membrane system are characterized by permeate flux and surface shear [4–6]. Source water quality, such as feed water composition, solution condition, etc. is an important factor for membrane filtration. In surface water treatment, natural organic matter (NOM) is thought to be a primary contributor to membrane fouling [7–9]. Factors potentially affecting membrane fouling by NOM include NOM characteristics such as particle/molecular size, hydrophobicity, charge density, and isoelectric point [4,5,10–13] and chemical functionality. The role of solution condition and molecular size appears to be well established, other factor, including the role of NOM polarity [1,9,13–16], is also studied, but their results are not well consistent. For example, many researchers have suggested that the humic substances, the hydrophobic fraction of NOM, is a major foulant which controls the rate and extent of fouling [1,14,15]. However, more recent studies have reported that hydrophilic (non-humic) NOM might be a more significant foulant. These results shown are based on the organic matter with different polarity and molecular weight (MW). Therefore, two kinds of organic matter with different polarity and similar MW were to investigate influences of compound polarity and structure on filtration performances of ultrafiltration membrane.

2. Materials and methods

2.1. Filtration organic matter

Based on polarity, organic matter can be divided into hydrophobic and hydrophilic fractions. In this study, two model compounds were selected to represent these fractions, namely tannin and polyacrylic acid. Relevant information on these compounds is shown in Table 1. The fouling behavior of each model compound was evaluated separately at a feed concentration of about 5 mg total organic carbon (TOC)/L in deionized water.

2.2. UF membrane and membrane module

A modified polyvinyl chloride (PVC) ultrafiltration hollow fibers with a nominal molecular weight cutoff (MWCO) of 80,000 Da and an internal diameter of 0.9 mm and an outer diameter of 1.4 mm were

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* Corresponding author.
E-mail addresses: guoxyan@nankai.edu.cn (X. Guo), shq73@eyou.com (H. Shao), hwl6626@163.com (W. Hu), beck0729@gmail.com (W. Gao), valenti_c@hotmail.com (X. Chen).

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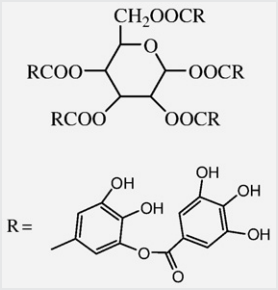
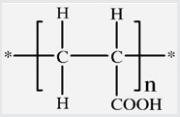
Table 1
Characteristics of model compounds.

Compound name	Represented fractions	Molecular structures	Molecular Formula	MW(Da)	Specific functional groups	Source
Tannin	Hydrophilic fraction		$C_{76}H_{52}O_{46}$	1701	Phenol hydroxyl	Guangfu Fine Chemical Engineering Institute, Tianjin, China
Polyacrylic acid	Hydrophobic fraction		$C_{84}H_{114}O_{56}$	2020	Carboxyl	ACROS Organics, New Jersey,USA

kindly provided by Litree Company (Hainan, China). Membrane modules consisting of 6 UF fibers with a length of 300 mm each were made in the laboratory. Membrane modules for the fouling/cleaning experiments were first cleaned with deionized water to remove the wetting agent, and then stored in deionized water with water replaced regularly. All membrane modules were rinsed thoroughly with deionized water prior to use.

2.3. Bench-scale fouling and cleaning experiments

Fouling and cleaning experiments were conducted in a bench-scale dead-end filtration system shown schematically in Fig. 1. The filtration unit comprises a feed tank, a peristaltic pump, a UF membrane module and a permeate tank, a flushing tank, and a backwashing tank. The permeate flux was determined every 5 min by collecting the permeate water for 30 s and measuring the permeate volume. A new membrane module was used for each experiment.

Every filtration experiment consists of 3 fouling–cleaning cycles. In the fouling stage of each cycle, a compound solution was filtered at a constant trans-membrane pressure (TMP) of 0.06 MPa for 30 min. Permeate samples were taken every 5 min and their TOC concentrations were determined using a TOC analyzer (Shimadzu Corporation, Kyoto, Japan, TOC-V $_{CPN(H)}$). At the end of the fouling stage, one fouled membrane fiber was cut from the membrane module for further characterization and the two roots of the cut membrane fiber were sealed. The rest of the fouled membrane fibers were cleaned by one of the three different methods: backwashing (0.2 MPa, 3 min), flushing&backwashing (the flushing cleaning was performed for 15 s to make the membrane fiber full, then backwashing was started in 0.2 MPa pressure, and flushing and backwashing were simultaneously run for 2 min 45 s) [17], and chemical cleaning with 0.5% NaOH. Every cleaning method was tested in a different experiment. After each cleaning, a cleaned membrane fiber was cut from the membrane module for further characterization and the two roots of the cut

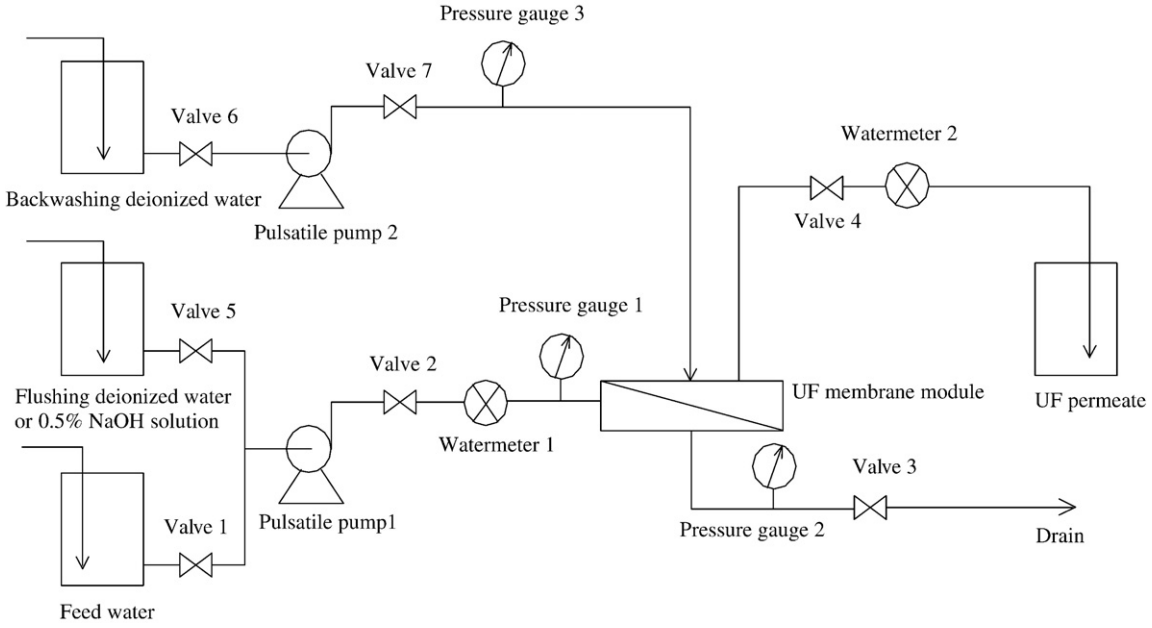


Fig. 1. Schematic diagram of the membrane filtration system.