Fouling mechanism and cleanability of ultrafiltration membranes modified with polydopamine-graft-PEG

Fang Li1,2, Chunhua Deng1,3 *, Chunhui Du4, Bo Yang1,2 and Qing Tian1,2
1College of Environmental Science and Engineering, Donghua University, Shanghai 201620, China
2State Environmental Protection Engineering Center for Pollution Treatment and Control in Textile Industry, Shanghai 201620, China
3Department of Environmental Science, Baylor University, Waco, TX 76798, USA
4College of Environmental Science and Engineering, Zhejiang Gongshang University, Hangzhou 310018, China

ABSTRACT
Membrane surface modification via grafting poly(ethylene glycol) (PEG) onto the coated polydopamine (PD) layer is an attractive strategy because it can improve the hydrophilicity of the membrane surface. Sodium alginate (SA), bovine serum albumin (BSA), and humic acid (HA) were used as model foulants to investigate the fouling mechanism and cleanability of modified membranes. The modification narrowed or blocked the membrane pores, which led to a reduction in the permeability of ultrafiltration membranes. A Hermia model was used to explore the fouling mechanism of the modified membranes. PD-g-PEG modified membranes exhibit a lower adsorption for the model foulants and a better cleanability than the unmodified membranes.

Keywords: polydopamine, organic matters, PEG, fouling mechanism.

INTRODUCTION
Because of the pressing demand for purified water, membrane processes, including microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), have received a great amount of attention over the last few decades (Dulebohn et al., 2014; Fane and Fane, 2005; Geise et al., 2010). Membrane fouling, which is responsible for continuous flux decline, is considered to be a major hurdle in the application of membranes for water and wastewater treatment. A large number of studies concluded that most of the fouling resistance was induced by dissolved organic matter in the feed. Consequently, frequent membrane cleaning and, ultimately, membrane replacement are required to maintain the membrane permeability, which increase the operational cost of membrane processes.

Membrane biofouling in water and wastewater treatment, especially irreversible fouling, is usually caused by dissolved organic matter (Mannina et al., 2010). These organic compounds are termed as extracellular polymeric substances (EPS), when they are bound to the flocs, or as soluble microbial products (SMP), when freely suspended in the supernatant. Numerous research studies have been conducted on membrane organic fouling, particularly related to EPS (Sheng et al., 2010; Mannina and Di Bella, 2012). These biopolymers include polysaccharides, proteins, humic acids, nucleic acids, and fatty acids (D’Abzac et al., 2010; Drews et al., 2006).

Membrane surface modification is an effective technology to improve the anti-fouling performance of the membranes (Shannon et al., 2008; Byun et al., 2013). Surface hydrophilization is one of the most attractive methods to reduce membrane fouling because it can decrease the adsorption and deposition of the contaminants onto membrane surfaces. The assumption appears to be reasonable because hydrophilic surfaces are able to attract a layer adjacent to them composed of water molecules and prevent hydrophobic foulants from adhering to membranes (Peeva et al., 2012), which leads to a stable and higher water flux at a constant pressure.

The use of PD-g-PEG is currently considered to be an attractive strategy in the membrane surface modification field, because it is able to remarkably enhance the surface hydrophilicity (Zhang et al., 2013; Eshet et al., 2011; Rana and Matsuura, 2010). Recently, some researchers developed a facile, two-step, dopamine-based process to coat a very thin PEG layer onto a membrane surface (Cao et al., 2013; Lee et al., 2007; Lee et al., 2009). A tightly adhesive polydopamine coating layer can be formed by treating a surface with an atri(hydroxymethyl) amino methane hydrochloride (TRIS HCl) buffered dopamine solution, regardless of the substrate material (Lee et al., 2008). Moreover, the coating process is simpler and more economical than alternative processes. A variety of membranes, including MF, UF, NF, and RO membranes, have been modified by PD and PD-g-PEG to exhibit a reduced BSA adhesion (McCloskey et al., 2010). In addition, PD and PD-g-PEG modifications are found to influence the pure water flux differently for each membrane, according to the layer thicknesses of the PD deposition; the coated layer thickness resulting from the subsequent PEG-grafting modification was much smaller than the pore size of the MF and UF membranes, but was larger than the pore size of the NF and RO membranes. However, recent reports revealed that membranes modified only by PD-coating did not behave as ideally as expected. Araujo et al. (2012) used PD coating of the membrane and the spacer to enhance biofouling control and found that biofouling was not eliminated. Similar results were obtained by Miller et al. (2012), who found that no reduction in biofouling was observed during longer biofouling experiments with PD-modified membranes, despite the reduced adhesion of BSA demonstrated in short-term tests. These phenomena have still not been fully explained.

Furthermore, the coated PD and grafted PEG layer might be unstable because of the physical adsorption of PEG-derivatized blocks or graft co-polymers on substrates (Wei et al., 2013). In addition, more research work should be conducted to understand the anti-fouling performance of organic foulants of membranes that are surface modified by PD-g-PEG.

* To whom all correspondence should be addressed.
e-mail: li369@hotmail.com
Received 21 March 2014; accepted in revised form 28 May 2015