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The antifouling performance of an ultrafiltration membrane with pre-deposited carbon nanofiber layers for water treatment

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ABSTRACT

In order to improve the performance of the ultrafiltration (UF) membrane process in drinking water treatment, in terms of permeate flux and natural organic matter (NOM) removal, a new form of carbon nanofiber (CNF) layer derived from bacterial cellulose (BC) was prepared and applied as a pre-deposited coating on the UF membrane surface. Using bench-scale, dead-end filtration tests, both CNF and CNF modified by ethanol treatment (M-CNF), were evaluated for the treatment of two model NOM solutions, namely bovine serum albumin (BSA) and sodium alginate (SA). The results showed that both types of coating were effective in mitigating membrane fouling (lower flux decline), with the mitigation increasing with the coating quantity, and also enhanced the removal of BSA and SA. In particular, the M-CNF layer at the greater loading (24 g/m^2) was able to reduce membrane fouling to a very substantial degree and achieve > 90% removal of BSA and SA. Characterization of the CNF and M-CNF layers showed significant differences in their morphological and structural properties which may explain the observed differences in their ability to reduce membrane fouling; protection of the UF membrane by the carbon nanofiber layers may be attributed to both physical separation and surface adsorption of the NOM biopolymers.

1. Introduction

In the past decade, ultrafiltration (UF) membrane technology has been increasingly applied in water treatment plants for drinking water supply in China and many other countries. Although various approaches to enhancing the performance of UF have received attention, fouling of the membrane still remains the principal operational limitation, affecting the process reliability and cost-effectiveness. Among the approaches being considered is the development of new, more efficient membrane materials, but progress so far has been slow [1]. Among the common materials used for water treatment membranes have been polyether sulfone (PES) [2,3], polyvinylidene fluoride (PVDF) [4,5], cellulose acetate (CA) [6], cross-linked polyamide (PA) [7], polycarbonate [8], and others. In many cases, pre-treatment processes are needed to remove the organic matter in the influent/raw water prior to the membrane to mitigate the membrane fouling.

As an alternative to conventional coagulation, floc separation and sand filtration, the use of powdered activated carbon (PAC) coupled with ultrafiltration (PAC-UF) is an emerging technology for the removal of NOM (natural organic matter) for drinking water [9–11], particularly for proteinaceous substances, and some fractions of humic-type substances [12]. As a sole pretreatment method, various studies have shown that PAC can remove some of the organic matter responsible for membrane fouling [13,14]. Yu and co-workers also found that PAC adsorption together with coagulation could decrease the amount of dissolved organic matter (DOM) reaching the membrane surface and the extent of internal membrane fouling [12]. However, some studies have indicated that the addition of PAC may induce a greater degree of membrane fouling in long-term operation [12]. Similarly, research conducted using other types of adsorbent particles added to UF systems to remove NOM and other contaminants from the raw water [15], showed contrary effects on membrane fouling; in some cases fouling was reduced, while in others it was exacerbated [16]. Also, a layer of either cellulose or (especially) polysulfone nanofibers on the surface of ultrafiltration membranes could improve the fouling resistance [17]. In other studies, particular nano-absorption materials such as heated iron

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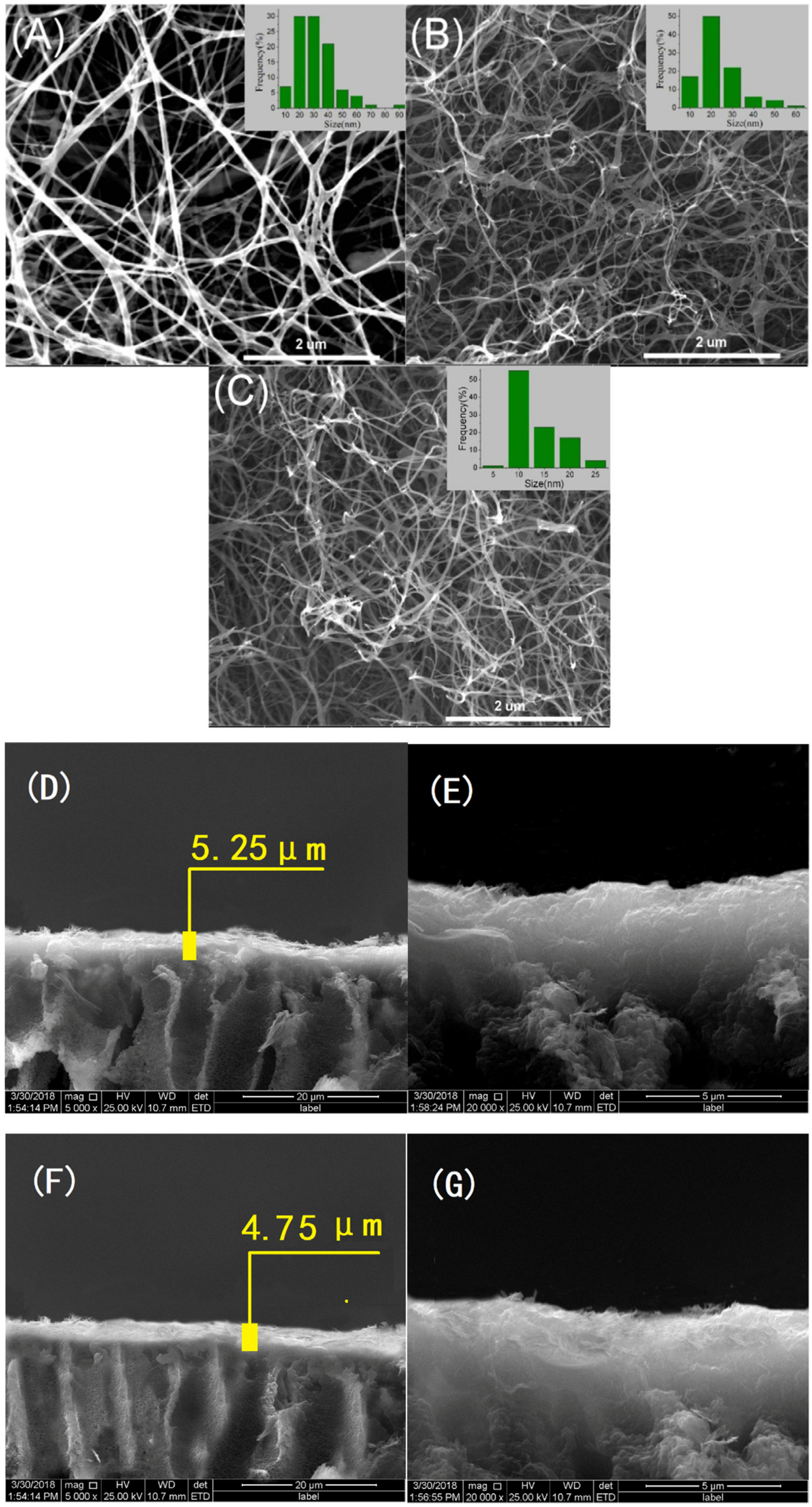

Fig. 1. SEM images of (A) BC aerogel, (B) CNF and (C) M-CNF; and inserts are statistical results of size distribution of the (A) BC nanofibers, (B) CNF and (C) M-CNF (by Smile View software; other conditions: voltage = 25 kV; magnification = 50,000 ×), and SEM cross-sectional images of CNF (D and E) and M-CNF (F and G) layers (with 6 g/m^2 loading).