Application of supercritical CO_2 for cleaning of reverse osmosis membrane biofouling

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ABSTRACT

Supercritical CO_2 (SC-CO_2) which has unique properties such as high diffusivity and solvent power was, for the first time, applied in a continuous flow mode of SC-CO_2 application to clean the fouled reverse osmosis (RO) membrane. The fouled RO membrane surface before and after SC-CO_2 application was analyzed by confocal laser scanning microscopy and scanning electron microscopy to observe any change of biofuling structure accumulated on the fouled surface of RO membrane. This study shows that SC-CO_2 application was very effective not only to remove biofouling structure from RO membrane surface, but also inactivate microbe relating biofouling on the RO membrane without any damages on RO membrane.

Keywords: supercritical CO_2, RO membrane, biofouling, cleaning

1. INTRODUCTION

In reverse osmosis (RO) membrane technology, biofouling which is the undesirable accumulation of microorganisms on submerged surfaces is one of major concerns because it causes not only increasing operation cost, but also deteriorating water quality (Hoek et al., 2008). Conventionally, chemicals and mechanical forces have been used for cleaning method of membrane biofouling (Flemming, 1997). However, these methods also have some drawbacks such as membrane damaging and cleaning limitation. Therefore, new cleaning techniques are required to solve these problems.

Supercritical fluids (SCFs) have been used as a cleaning solvent due to its unique properties such as high solvent power and diffusivity (Zhang & Han, 2007). In addition, SC-CO_2 is well known to have good disinfection effect for various microorganisms (Spilimbergo et al., 2007). This study was attempted to apply SC-CO_2 fluid to clean the fouled RO membrane.

2. MATERIALS AND METHODS

2.1. Preparation of RO membrane sample

Approximately one year old fouled RO membrane (RE-SR, Woongjin Inc., Seoul, Korea) was taken from real RO desalination plant in Korea. The RO membrane was made of polyamide thin-film composite and configured by spiral-wound type (plate-sheet). The fouled plate-sheet of membrane was cut to make appropriate size (3 cm × 7 cm) for membrane cleaning experiment by SC-CO_2.

2.2. SC-CO_2 cleaning system and procedure

The continual flow SC-CO_2 cleaning system (Hanyang Inc., Seoul, Korea) was built up as shown in Fig. 1. The membrane sample was inserted into the high-pressure reactor and was enclosed and immersed in heating bath to maintain a constant temperature (35^{o}C) during experiment. Super-cooled liquid CO_2 was pumped by high-pressure pump (Thar Technologies, Inc., USA) to reach the desired pressure (100 bar). In the SC-CO_2 cleaning system, the water was used to co-solvent in order to improve the effect of RO membrane cleaning. In addition, the effluent of CO_2 or water saturated CO_2 were continually trapped using trapper contained 10 ml of distilled water in order to analyze extracted molecules such as polysaccharide and protein associated with fouled membrane. The operation flow rate of CO_2 was 10 ml/min for 1 h.

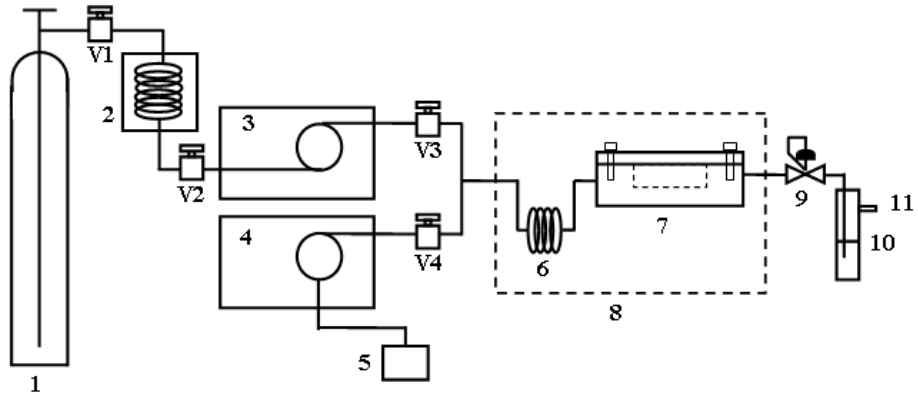

Fig. 1. Schematic of continual flow SC-CO_2 cleaning set-up: (1) CO_2 cylinder; (2) pre-cooling unit; (3) high-pressure pump 1; (4) high-pressure pump 2; (5) co-solvent (water); (6) pre-heater; (7) high-pressure reactor; (8) thermostated bath; (9) back pressure regulator; (10) trap; (11) vent; (V1) to (V4) high pressure valves.

2.3. Analysis of fouled RO membrane before and after SC-CO_2 cleaning

Biofouling structure and cell viability of fouled RO membrane before and after SC-CO_2

treatment was examined by confocal laser scanning microscopy (CLSM; Nikon 90i, Tokyo, Japan) with BacLight Live/Dead kit (Molecular probes, Eugene, USA). All images were analyzed by analysis program (IMARIS; Bitplane AG, Zurich, Switzerland). The fouled RO membrane was also analyzed by scanning electron microcopy (SEM) to examine the cleaning capability of SC-CO_2 application.

3. RESULTS AND DISCUSSION

Fig. 2 shows 3D images of biofouling structures of fouled RO membrane before and after SC-CO_2 application. As shown in Fig. 2(a), before SC-CO_2 application, the surface of fouled RO membrane was covered with a large amount of biomaterials associated with biofouling. Furthermore, the microbe of fouled RO membrane surface was mostly alive as shown in green color. In contrast, the surface of fouled RO membrane was cleaned by SC-CO_2 application and the microbe of fouled RO membrane was found mostly dead as shown in red color (Fig. 2(b)). These observations clearly show that the SC-CO_2 application can achieve not only removal biofouling on the RO membrane but also inactivating microbe on the fouled RO membrane.

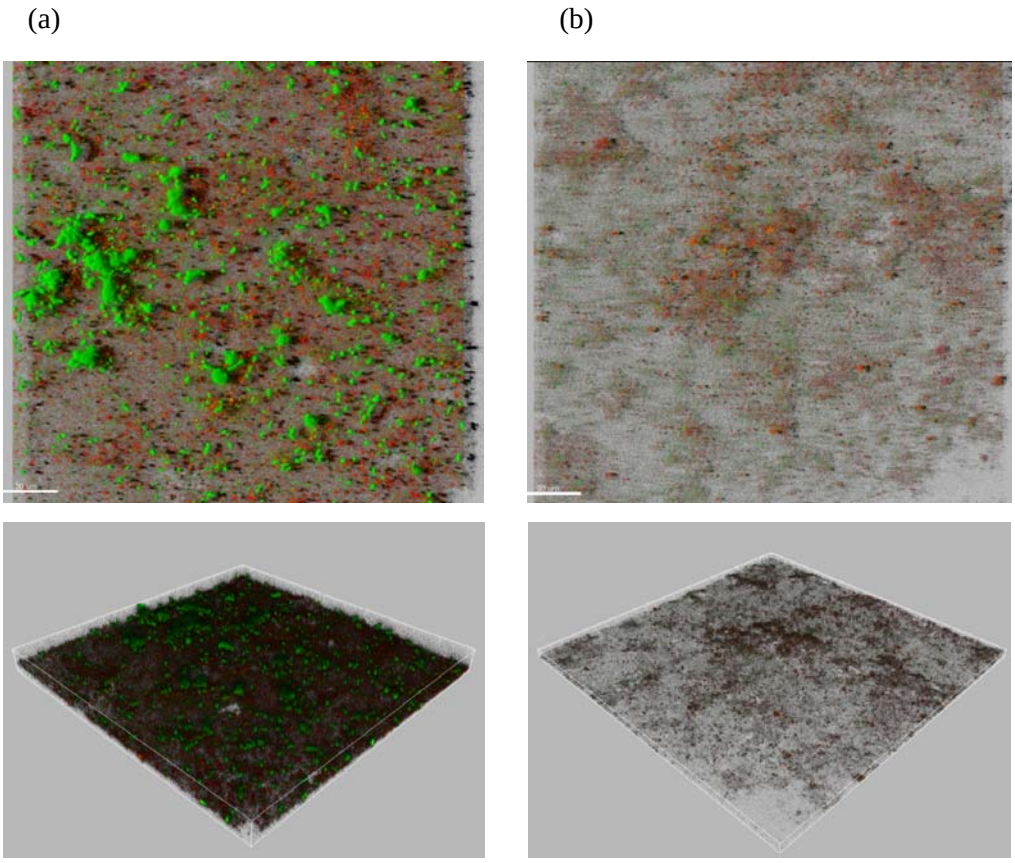

Fig. 2. 3D images (top row) and side-view projection (bottom row) of CLSM showing the spatial structure of fouled RO membrane: (a) before, (b) after SC-CO_2 application.

Fig 3 shows SEM images of fouled RO membrane surface before and after SC-CO_2 application as compared with non-fouled RO membrane surface. The fouled RO membrane became significantly cleaned like new RO membrane after SC-CO_2 application (Fig 3). This observation implies that SC-CO_2 may not cause significant deteriorating of the fouled RO membrane.

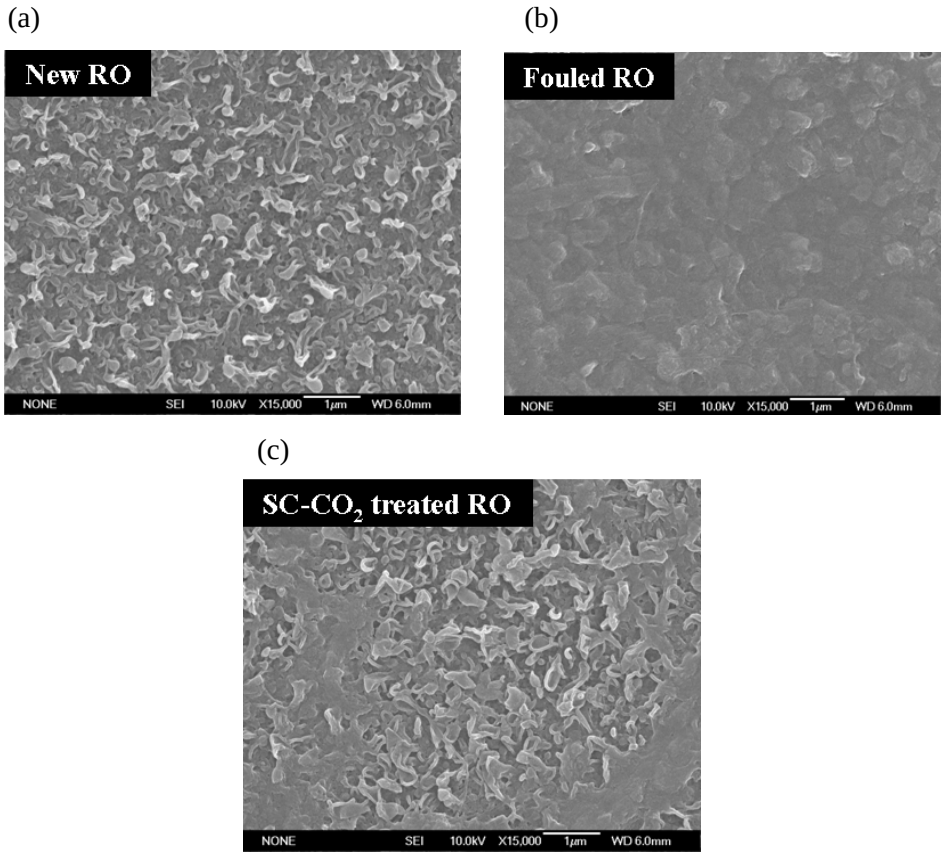

Fig. 3. SEM images of each membrane surface: (a) New RO, (b) fouled RO, (c) SC-CO_2 treated RO.

4. CONCULSION

This study reports for the first time that the fouled RO membrane was significantly cleaned by SC-CO_2 application without deteriorating RO membrane. This result implies that SC-CO_2 can be used to clean the fouled RO membrane as alternating membrane cleaning technique.

REFFERENCE

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