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Polyethersulfone/Polyamide11Cost Effective, Antifouling-Nanofiltration Blend Membrane

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Abstract
Nanofiltration membranes (NF) are considered and used extensively in seawater softening, food, textile, and mining industries for the removal of di-and multi-valents to increase RO lifetime by decreasing fouling rates, and chemical cleaning intervals. In this work, blend membranes of polyethersulfone and polyamide11 were prepared by phase inversion process. The membranes were characterized by scanning electron microscopy (SEM),pore size distribution, mechanical properties and membranes performance. The results indicated that, the membrane (N2), which was prepared using PA11 (1 wt%) with a solution of sodium dodecyl sulphate (0.5wt%) and TiO2 (1 wt%) provides the best performance according to rejection percentage. Where, the rejection percentage of magnesium sulfate reached 99 %, 97% and 91% as a function of feed synthetic salt solution of concentration 1g/l, 2 g/l, and 5 g/l respectively. Permeate flux of (N2) was the lowest one due to having a dense top layer of this membrane and low mean pore size (7.7 nm) which was 66.7 L/m2.h, 64.2 L/m2.h and 53.5 L/m2.h as a function of feed synthetic salt solution of concentration 1g/l, 2 g/l and 5 g/l respectively. The fouling test was carried out using methylene blue dye, where the membrane (N2) exhibits good antifouling properties.

Keywords: Nanofiltration; Polyethersulfone; Polyamide11; Blend membrane; Membrane performance

1. Introduction

Nanofiltration membranes (NF) are considered low-pressure reverse osmosis (RO) membranes. Where, they are used in seawater softening, food, textile, and mining industries [Martın et al, 2015; Jafarzadeh et al 2015]. NF membranes depend on a transport mechanism of solution-diffusion, that operates at the interface of porous and nonporous membranes by sieving and diffusion transport mechanisms [Jhaveri et al, 2016; Elgindi et al 2016].

Integrated system between NF and RO reduces the cost of RO by decreasing the power of the high-pressure pump. Characteristics of NF membranes according to rejection percentage are 30–40% NaCl rejection, 85–90% MgSO4 rejection, 98% sucrose rejection and 99% raffinose rejection [Borea et al, 2018; Bhattacharyya et al, 1989; Otitoju et al, 2018].

This work goal depends on development now kind of nanofiltration blend membranes using poly-ethersulfone and polyamide 11 to provide antifouling NF membrane with highly mechanical properties.

2. Methodology

2.1. Nanofiltration membrane preparation

Blend PES/PA11 membranes were prepared using a phase inversion process. The polymer dope solutions were dissolved in NMP. The mixing process was carried out for 18 hrs.

2.2. Membrane characterization

Prepared membranes were characterized by Scanning electron microscopy (SEM), Mechanical properties of prepared membranes were studied to determine the effect of the blending percentage on the membrane mechanical properties.

2.3. Membrane Performance

For nanofiltration test, the laboratory cross flow desalination unit consists of a flat sheet membrane module of three openings for feeding concentrate and permeates connected with a high-pressure pump. The permeation tests were carried out at ambient temperature under an operating pressure up to 15 bar; the feed solution has a capacity of 20 L. The effective surface membrane area was of (89.89cm2). Magnesium sulfate was used in a different concentration of synthetic solutions (1, 2 and 5 g/l) for this test.

2.4. Membrane fouling testing

Fouling performance of the prepared membranes N1 and N2 were tested by measuring of permeate flux recovery after fouling by emulsion of 10 g oil/ L. The fouling test for prepared membranes N1 and N2, where distilled water fluxes before and after oil passing was measured. Also, the permeate flux solution from oil solution was also measured. The flux recovery ratio (FRR) and resistance parameters were calculated to determine the anti-fouling properties.

3. Results

3.1. Membrane characterization

Fig. 1. Illustrates the SEM cross-section photos of prepared membranes. N1 is PES membrane without any addition, which displays spongy structure with top dense layer and the porous bottom layer has non-woven support. The N2 membrane has 0.5 wt% PA11 with NS solution composed of SDS 0.5 wt%, TiO2 1 wt% were dissolved in distilled water. SEM image indicates that the appearance of finger-like structure in the sublayer of the membrane with a dense top layer and porous bottom nonwoven layer. The N3 membrane has 1 wt% PA11 with the same NS solution (SDS 0.5 wt%, TiO2 1 wt%) in the polymeric solution provides wide finger-like structure in the sub layer of the membrane with dense top layer and a porous bottom layer of non-woven support. The N4 membrane provides again the spongy structure, where the NS solution didn't use in preparation of this membrane, SDS was used only as a surfactant to provide antifouling properties of the membranes.

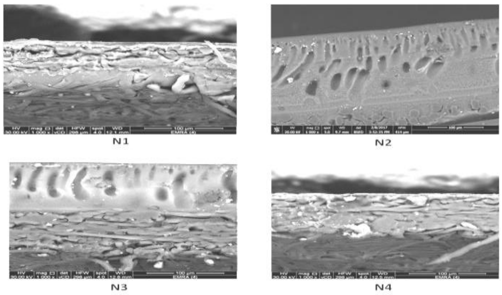

Fig.1. SEM photos for nanofiltration membranes

The addition of PA 11 percentage with the nanomaterial solution (NS) leads to the maximum tensile strength (6.3 N/cm2) and the maximum elongation% (20 %) are reached when the membrane blended with 0.5 wt% of PA11 with NS (0.5 wt% SDS and 1 wt% TiO2). While increasing the percentage of PA11 to 1 wt% reduces the mechanical properties, where tensile strength reached to 4.2 N/cm2 and the maximum elongation% reached to 17.2 %.

3.2. NF Membranes performance test

Magnesium sulfate was used in the different concentration of synthetic solutions (1, 2 and 5 g/l) for membrane performance test. Figs. (2, 3) show the performance of prepared membranes in terms of magnesium sulfate rejection percentage and permeate flux respectively.

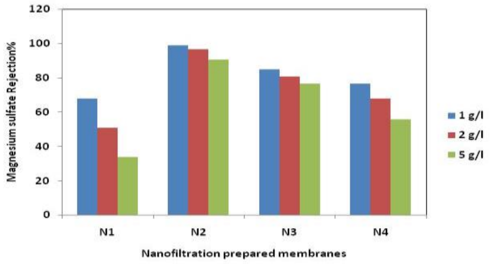

Fig.2. Magnesium sulfate percentage separation as a function of concentration using prepared Nanofiltration membranes

The experiments were performed under operating pressure of 15 bar. It is clearly from Figs. (16, and 17) that the N2 provides the best performance according to rejection percentage. Where, the rejection percentage of Magnesium sulfate reached 99 %, 97% and 91% as a function of concentration 1g/l, 2 g/l, and 5 g/l respectively. Permeate flux of N2 was lowest one according to the dense top layer of membrane and low mean pore size (7.7 nm) which was 66.7 L/m2.h, 64.2 L/m2.h and 53.5 L/m2.h as a function of concentration 1g/l, 2 g/l and 5 g/l respectively.

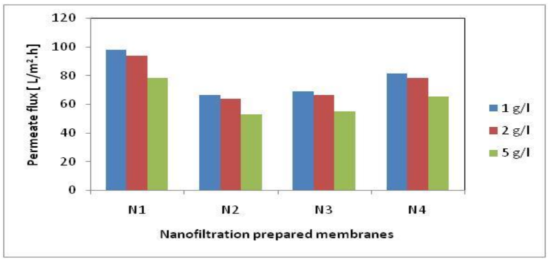

Fig.3. Permeate flux as a function of concentration using prepared Nanofiltration membranes

3.3. Membrane fouling testing

The fouling test results indicate that adsorption of oil droplets on the membrane surface leads to reversible fouling, that was easily removed by surface wash, where Rr was 23.9% for N1 and 24.6% for N2.

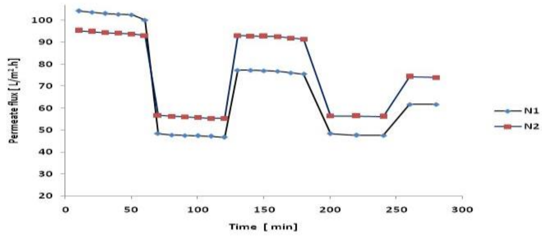

Fig. 4. Fouling test as a function of time

On the other hand, irreversible fouling produced due to adsorption of oil droplets on the membrane surface and clogging the pores of the membrane by oil droplets on the surface, where Rir was 2.2% for N1 and 0.93 % for N2. However, the FRR for N1 was 97 % and for N2 was 98%.

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