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Effect of silica on the properties of cellulose acetate/polyethylene glycol membranes for reverse osmosis

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HIGHLIGHTS

- 2-stage phase inversion protocol; involving TIPS and controlled evaporation.
- Silica is used as an additive to augment permeation performance.
- Addition of silica enhanced the fouling resistance remarkably.
- Optimum loading of silica particle is required for maximum performance.

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ABSTRACT

In this work, a series of cellulose acetate/polyethylene glycol-600 membranes, with varying ratios were prepared by 2-stage phase inversion protocol. The permeation properties were studied by subjecting membranes in indigenously fabricated reverse osmosis plant. After optimization of different CA/PEG ratios, the membrane with highest salt rejection capacity was selected and modified with varying amount of silica. The Modified membranes were characterized for their permeation properties, hydrophilicity, compositional analysis, thermal stability, mechanical strength and morphological studies. Silica significantly influenced the permeation performance of composite membrane. The flux enhanced from 0.35 to 2.46 L/h m^2 along with an 11.41% relative increase in salt rejection. The hydrophilicity was significantly enhanced by the addition of silica. In FTIR spectra, the broadening of the peak around 3500 cm^{-1} and emergence of peak at 950 cm^{-1} specified the incorporation of silica particles. The thermal analysis indicated the relative increase in degradation temperature (T_{max}) and glass transition temperature (T_g) for CPS-5 membrane. The mechanical stability of the modified membranes, increased initially, but declined with further addition of silica. The results indicated that the incorporation of SiO_2 content in the casting solution improved the fouling resistance of the membranes.

1. Introduction

Membranes and membrane processes subsist as old as life [1–4]. Recently, synthetic membrane processes have appeared among the most innovative technologies to attain a variety of goals ranging from molecular separation to concentration of products [5]. The intrinsic characteristics of membranes like high efficiency, simplicity, selectivity, low energy consumption and good stability make membranes as an integral part of various chemical industries [6,7].

Membrane based desalination processes involve reverse osmosis (RO), electro dialysis, forward osmosis, ultrafiltration and nanofiltration [8,9]. The RO process was commercialized in 1970 and today it is a leading membrane technology representing 80% of total desalination plants [10–12].

An ideal RO membrane should possess the resistance to chemical attack, excellent separation performance, good mechanical and thermal stability [13]. The performance of a membrane is notably influenced by its constituents, which affect many properties [14,15]. Various polymers have been used to synthesize membranes, but cellulose acetate (CA) membranes are well accepted due to their good transport characteristics, low protein adsorption, excellent water affinity, appropriate mechanical strength, excellent film-forming properties and lower cost [16,17]. However, CA has poor thermal stability, lower chemical resistance, inferior mechanical strength and vulnerable to fouling resistance. Therefore, attempts have been made to improve the performance of CA by developing hybrid organic–inorganic membranes. Few researchers have investigated the effect of alumina (Al_2O_3), zirconia (ZrO_2), titania (TiO_2), silver

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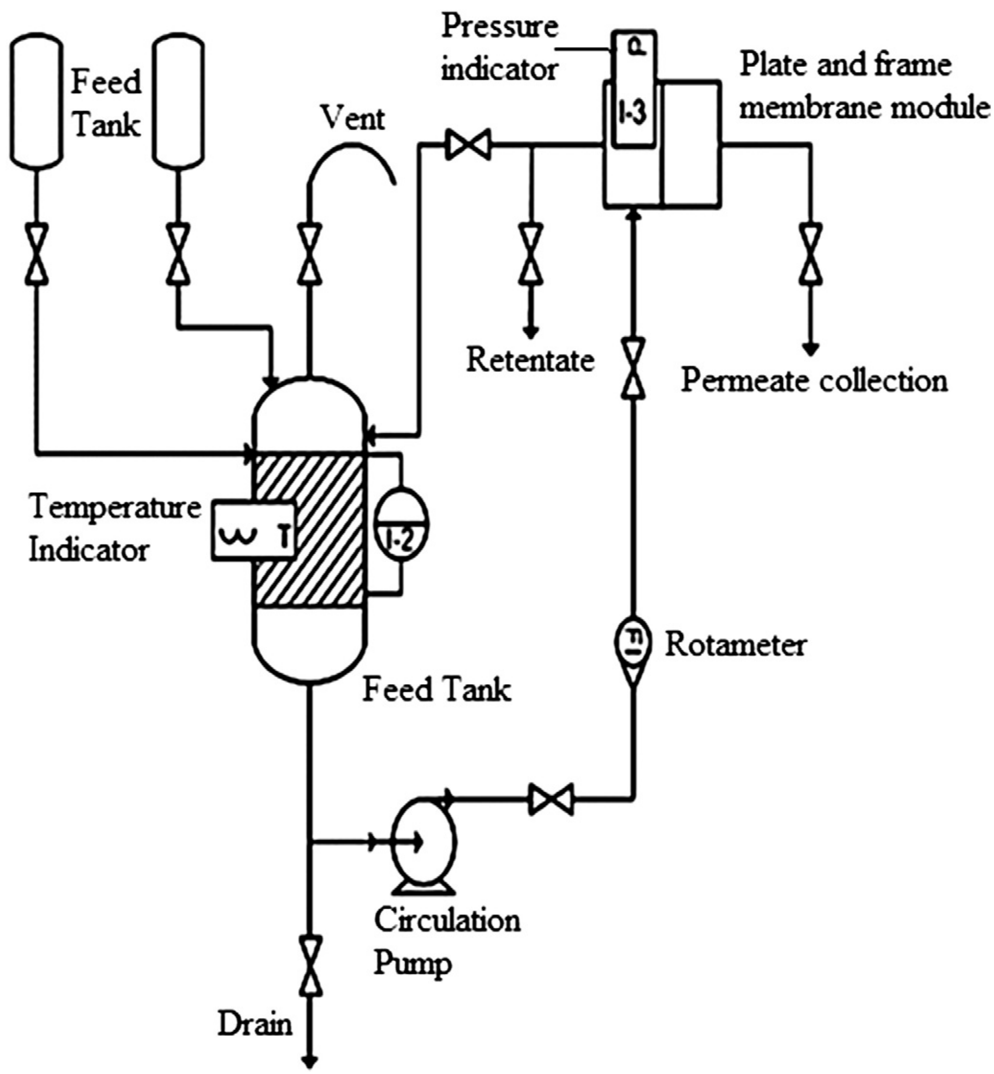

Fig. 1. A schematic of reverse osmosis rig.

and silica (SiO_2) particles in various polymeric materials [18–20]. The resultant hybrid membranes have been reported to increase the flux and mechanical strength, upon increasing the concentration of inorganic particles [21,22]. SiO_2 particles have attracted particular attention owing to their special properties like small size, thermal resistance, fine suspension formation in aqueous solution, strong surface energy and relatively inert material.

Polymeric RO membranes are synthesized through phase inversion protocol. It is the most versatile technique to obtain a variety of morphologies ranging from microfiltration membranes with very porous structures, to more dense reverse osmosis membranes [23]. The concept of phase inversion involves an array of different methods such as diffusion-induced phase separation, vapor-phase precipitation, phase inversion by controlled evaporation and thermal-induced phase separation (TIPS) [24]. All the methods involve complex multi-component

Table 1
Effect of concentration of CA/PEG on water content, flux, salt rejection and membrane permeability.

Membrane type	Water content (%)	Flux (L/h m^2)	Salt rejection (%)	Membrane permeability ($\times 10^{-4}$ L/h m^2 kPa)
CA/PEG-1	61.50	0.87	52.00	2.70
CA/PEG-2	58.70	0.70	60.00	2.50
CA/PEG-3	53.95	0.46	69.20	2.00
CA/PEG-4 (Control)	51.11	0.35	81.50	1.68

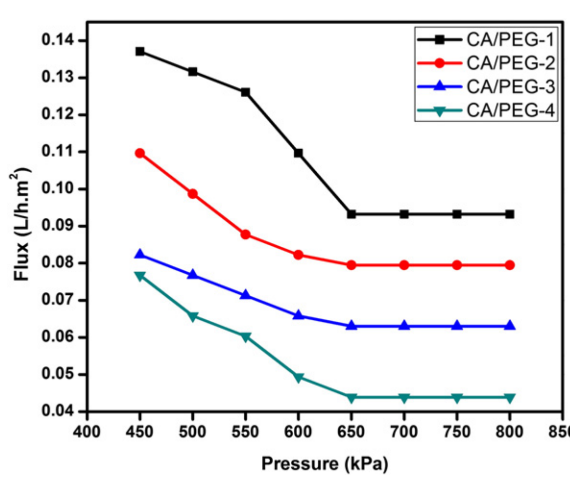

Fig. 2. Relationship between pressure and flux.