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# Preparation, Characterization and application studies of cellulose acetate – poly acrylic acid blend ultra filtration membranes

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**Abstract:** A series of ultrafiltration (UF) membranes were prepared through phase inversion technique by blending cellulose acetate (CA) with poly acrylic acid (PAA) in the blend compositions of 100/0, 99.5/0.5, 98.5/1.5 and 97.5/2.5% blend compositions. Prepared membranes were subjected to membrane characterization studies. Morphological studies revealed the increased number of pores with the addition of PAA, indicating higher fluxes for the blend membranes. Thermal stability of the blend membranes increased with the addition of PAA to the base polymer. UF characterization studies on the blend membranes clearly indicated the increased water uptake and pure water flux with the increase in the concentration of the PAA in the blend composition. Membrane characterization and performance studies clearly indicated the better performance of 97.5% CA – 2.5% PAA blend membrane in comparison with other synthesized UF membranes as well as the pure CA membrane.
**Keywords:** Ultra filtration, Cellulose acetate, Poly acrylic acid, Membrane blending, Membrane characterization, Membrane application.

## 1. Introduction & Experimental procedure

Membrane separation is a promising technology for the downstream processing especially with regard to effluent treatment of the process industries. The basic phenomena of membrane separation along with its commercial importance have been extensively reported in literature [1,2]. Porous polymeric materials and their blends have played an important role in membrane development for separation applications such as ultrafiltration (UF), microfiltration and nanofiltration. Improvements in the polymer membrane properties in terms of porosity, hydrophilicity, thermal stability, mechanical strength, flux and solute rejection have been carried with addition of modifiers to the base polymer [1,2]. Cellulose Acetate (CA) based UF filtration membranes are widely used for membrane synthesis for effluent treatment. However, pure CA membranes suffer from the limitation of lower fluxes. Blending the base CA polymer with several modifiers has resulted in membranes with enhanced ultrafiltration properties [3–5]. Poly Acrylic Acid (PAA) has been successfully blended with other polymer based membranes resulting in the enhanced features of the respective base membrane. In this current study, a series of UF membranes with CA as base polymer and poly acrylic acid (PAA) as modifier have been synthesized with varying compositions. The prepared membranes have been characterized for its membrane features and the better blend membrane was subjected to application studies and the results were compared with pure CA membrane's performance.

CA based asymmetric UF membranes are predominately prepared by phase inversion technique. Standard procedure of phase inversion method for membrane preparation as described in literature [5], was adopted for the membrane synthesis. The cast solution composition for the various membrane blend preparation is as shown in Table 1.

Scanning electron microscopy (SEM) (Supra 55-Carl Zeiss, Germany) was used to analyze the morphology of the blend membranes through standard morphology study procedure. Pure water flux, measured at different pressures, was determined using the equation, $J_w = [Q / (A \Delta T)]$ where, $J_w$ – permeate flux (lit $m^{-2}$ $h^{-1}$), Q – quantity of permeate (lit); A – membrane area ($m^2$), ΔT – sampling time (h). The hydraulic resistance for a given blend membrane was evaluated from the inverse of the slope for the plot between water flux ($J_w$) and transmembrane pressure difference (ΔP). Thermal stability analysis (Thermo gravimetric analysis) for a given blend membrane was carried out using STA 409PC Seiko Instrument Inc through standard thermal stability study procedure, from 50 $^oC$ to 450 $^oC$ with a constant heating rate of 10 $^oC$/min. The glass transition temperature for the representative blend membrane was also obtained from the thermal analysis. Solute rejection percentage was calculated using the equation, $\%SR = [1-(C_p/C_f)]*100$ where, $C_p$ and $C_f$ are solute concentrations of permeate stream and feed stream, respectively.

## 2. Results & Discussions

The CA – PAA blend membranes showed better porosity, both in the skin as well as in the support layer, when compared to pure CA membrane. As shown in figure 1, it could be seen that the number of pores got increased with the increase in the PAA concentration in the blend membranes.

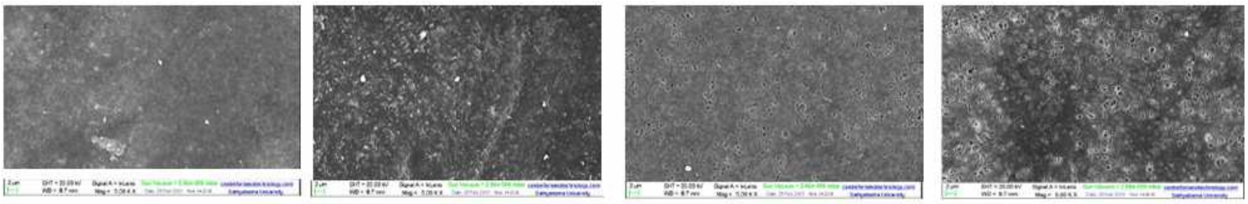

Figure 1 a Figure 1 b Figure 1 c Figure 1 d

**Figure 1:** SEM images of pure and blend membranes
a) 100% CA b) CA– PAA (99.5/0.5%) c) CA– PAA (98.5/1.5%) and d) CA– PAA (97.5/2.5%)

Ultrafiltration characterization tests for the CA – PAA blend UF membranes are presented in Table 1. Pure water flux and water uptake increased with increase in PAA concentration in the blend membranes due to the hydrophilic nature of PAA. The resistance of the blend membranes recorded a decreasing trend with the increasing concentration of PAA modifier which can be attributed to the increasing porosity. Results of the thermal analysis study clearly indicated the increased thermal stability of the blended membranes. The weight loss percentage of the membrane (with increase in temperature) was reduced by the addition of PAA modifier, thus exhibiting the enhanced temperature tolerance of the blend membranes as evident from the glass transition temperature ($T_G$) measurement for the blend membranes given in Table 1.

**Table 1: UF characterization & Thermal stability results for the pure and blended membranes**

| Membrane blend Composition | | Pure Water flux (lit $m^{-2}$ $h^{-1}$) | | | | | | Membrane Hydraulic Resistance (kPa $m^2$ h $lit^{-1}$) | Water uptake (%) | Glass Transition Temperature ($^oC$) |
|---|---|---|---|---|---|---|---|---|---|---|
| **CA (%)** | **PAA (%)** | **69 kPa** | **138 kPa** | **207 kPa** | **276 kPa** | **345 kPa** | **414 kPa** | | | |
| 100 | 0 | 1.1 | 2.2 | 3.2 | 4 | 5 | 5.61 | 76.34 | 33.3 | 204.3 |
| 99.5 | 0.5 | 2 | 8.1 | 12.9 | 15.2 | 17.5 | 18.1 | 21.74 | 51 | 210.5 |
| 98.5 | 1.5 | 9 | 19 | 21.7 | 31 | 35.7 | 40.3 | 11.27 | 59 | 218.3 |
| 97.5 | 2.5 | 13 | 25 | 28.4 | 44.2 | 39.1 | 44.2 | 10.16 | 66.6 | 223.4 |

From above results, it is evident that the 97.5% CA – 2.5% PAA blend membrane had better ultrafiltration characteristics among other blend membranes. Hence this blend membrane was subjected to performance test in terms of effluent treatment. Results of the solute rejection studies for the 97.5% CA – 2.5% PAA blend membrane are given in Table 2. BOD, COD and sulphate content of the feed, permeate and reject streams were characterized. The results of performance tests indicated that the blend membrane reported an almost equivalent rejection percentage but with an increased flux as compared with pure CA membrane.

**Table 2: Solute rejection studies for 100% CA and 97.5% CA – 2.5% PAA blend membrane**

| Sample Type | BOD | COD | Sulphates | % Solute |
|---|---|---|---|---|
| Feed Effluent | 364 | 1184 | 2840 | -NA- |
| 100% CA Reject | 372 | 1560 | 2641 | 84.12 |
| 100% CA Permeate | 12 | 120 | 99 | |
| CA–AC (97.5/2.5%) Reject | 372 | 1419 | 2421 | 80.74 |
| CA–AC (97.5/2.5%) Permeate | 26 | 393 | 141 | |

## 3. Conclusions

A novel series of cellulose acetate membrane (CA) blended poly acrylic acid (PAA) ultrafiltration membrane was synthesized in varying compositions and subjected to membrane characterization analysis. Results indicated enhanced pores statistics, water permeability, hydrophilicity and thermal strength with increase in PAA concentration in the membrane composition. The 97.5% CA – 2.5% PAA blend membrane outperformed among the synthesized blend membranes. Solute rejection performance test on this blend membrane clearly indicated that the blend membrane reported an almost on par solute rejection percentage with an increased flux, as compared with pure CA membrane. Thus the 97.5% CA – 2.5% PAA blend membrane is very potential candidate for higher flux membrane separation applications.

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