

Mixed Matrix Membranes Of Sodium Alginate And Hydroxy Propyl Cellulose Loaded With Phosphotungstic Heteropolyacid For The Pervaporation Separation Of Water – Isopropanol Mixtures At 30⁰ C

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Abstract: Mixed matrix membranes (MMMs) of Sodium alginate / Hydroxyl Propyl Cellulose (SA/HPC) blends loaded with Phosphotungstic acid (PWA) and cross linked with gluteraldehyde have been prepared by the solution casting technique. Pervaporation (PV) experiments have been performed at 30⁰C to separate water – isopropanol feed mixtures containing 10-15 wt % of water. The membranes were characterized by Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction study(XRD) to confirm cross linking and assess the intermolecular interactions. Thermal stability and crystallinity were determined from thermo gravimetric analysis (TGA) and differential scanning calorimetry (DSC) studies. The morphology of membranes was characterized by SEM studies, which indicates good compatibility of these membranes. Sorption studies were carried out to evaluate the extent of interaction and degree of swelling of the membranes, in pure liquids as well as mixtures of water and isopropanol. The pervaporation performance was evaluated by varying experimental parameters such as feed composition, different polymer compositions and found to be potential membranes for separation of water- isopropanol mixtures. The results reveal that the MMMs of SA-HPC-3 shows flux is of the order of 0.3460 kg m⁻²h⁻¹ and selectivity of the order of 1657. From this it is concluded that the present blend membrane is a promising candidate for dehydration of aqueous isopropanol. Flux of the blend membranes decrease with increasing concentrations of PWA; however, a significant improvement in PV performance was observed for PWA- loaded mixed matrix membranes (MMMs) compared to the pristine SA/HPC blend membrane.

Keywords: Pervaporation; Sodium alginate / Hydroxy propyl cellulose blends; Phosphotungstic acid; Water –isopropanol mixture; Membrane characterization.

1. INTRODUCTION

Membranes can be used for the selective removal of water from aqueous organic mixtures. Pervaporation is a still underestimated but continually developing membrane technique suitable for the separation of special liquid mixtures [1-4]. One of the main applications of pervaporation is the dehydration of organics, including ethanol, isopropanol and ethylene glycol etc. This form of pervaporation is applied in several fields, including the breaking of azeotropic or binary mixtures, batch wise dehydration in discontinuous processes and dehydration of multicomponent mixtures.

In recent times several workers developed MMMs by incorporating metal containing heteropoly acids (HPAs) for the PV separation of alcohol-water mixtures [5-12]. Heteropoly acids (HPAs) are the widely used inorganic materials that contain ring transition metal oxygen anion clusters, which exhibit a wide range of well – defined molecular structures, surface charge densities, chemical and electronic properties [13] in addition to their inherent catalytic properties [14-16]. The heteropoly acids (HPAs) that are strong Bronsted acids have been widely used as solid electrolytes in catalysis reactions [17-18]. Their water solubility has been advantageously utilized in considering them as fillers in polymer matrices to improve the membrane performance [19-20]. Among these, Keggin – type HPAs have been widely investigated as the catalytic materials [21]. Our present approach is to further explore the possibility of developing organic-inorganic hybrid membranes by incorporating HPAs that have the most potential material for pervaporation studies. HPAs are a subset of the well-known inorganic metal oxides called polyoxometalates [22- 23]. In this work, we have chosen phosphotungstic acid (PWA) that consists of Keggin unit as a primary structure, a secondary structure i.e., regular three dimensional assembly of heteropolyanions with counter cations (protons) and additional water molecules [24]. Hydrophilic membranes are widely used in PV dehydration of organic mixtures. Hydrophilic groups absorb water molecules preferentially, leading to high flux and selectivity. Among natural polymers, sodium alginate (SA) and Hydroxy propyl cellulose (HPC) has been widely used by several works for pervaporation studies. But blend membranes of these polymers have not been tried for pervaporation studies. Again no efforts were made by

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incorporating fillers in these blend membranes for improving this separation performance. SA, is a water soluble polymer, can be readily crosslinked with glutaraldehyde (GA) [25] and hence, its membrane can be developed for use in organic dehydration. Sodium alginate is an anionic natural micro molecule, which is composed of poly β -1, 4-D-mannuronic acid (M units) and α -1, 4-L-glucuronic acid (G units) in varying proportions by 1, 4-linkages. In addition, sodium alginate can be easily modified through various chemical or physical methods such as grafting copolymerization with hydrophilic cellulose monomers, polymer blending [26] and compounding with other functional components [27]. Another polymer chosen for blending is Hydroxy propyl cellulose (HPC), which is an alkyl-substituted hydrophilic cellulose derivative that not only has phase transition behavior in aqueous solution [28] but this also miscible with SA. The material is soluble in water as well as polar organic solvents [29]. But also has many advantages such as excellent film forming properties, biodegradability and biocompatibility etc. In the present study it is planned to prepare blend membranes of SA/HPC natural polymers and incorporated with Heteropoly acid of PWA for the pervaporation studies. Isopropanol is chosen in the present study, since it is a very important and commonly used solvent in biopharmaceutical and chemical industries. It is miscible with water in all proportions and forms an azeotrope at 12.5wt% of water. Conventional methods for separation of isopropanol-water mixtures include azeotropic distillation and extractive distillation, which are of high energy consumption and waste generation [30]. In this study, mixed matrix membrane of SA/HPC blends is loaded with phosphotungstic acid (PWA) aiming at obtaining high permeability and selectivity simultaneously for pervaporative separation of isopropanol-water mixture. Furthermore, the effect of blend composition in membranes, feed concentration and the perm selectivity has also been investigated and presented here.

2. Experimental

2.1. Materials

Sodium alginate (SA) having a viscosity average molecular weight of 500,000, Acetone, Hydrochloric acid and phosphotungstic acid (PWA) were purchased from s.d. fine chemicals, Mumbai, India. Hydroxy propyl cellulose (HPC) with a molecular weight of $\approx 15,000$ was purchased from Aldrich Chemical Company, Milwaukee, WI, USA. Isopropanol was purchased from Qualigens fine chemicals, Mumbai, India, and Glutaraldehyde was purchased from Merck chemicals, Mumbai, India. Deionized water having a conductivity of $20\mu\text{S}/\text{cm}$ was used for the preparation of feed solution, which was generated in the laboratory itself.

2.2. Preparation of membranes

MMMs of SA/HPC blends loaded with PWA membranes were prepared by solution casting and solvent evaporation technique. In brief, different ratios of SA and HPC so as to make total weight of 4 gm were dissolved in 90 mL of distilled water individually at room temperature by constant stirring on a magnetic stirrer (Remi Equipment Model 2MLH, Mumbai, India) for 24 h to get homogeneous solution of SA/HPC blend. In separate flasks, 0.2, 0.3g of PWA was dispersed in 10 mL of water, sonicated for 2h,

added individually to the previously prepared SA/HPC blend solution. The whole mixture was stirred for 24 h, filtered and poured onto a perfectly aligned clean glass plate in a dust free environment for casting the membranes using a doctor's blade. The membranes after drying at ambient temperature (30°C) were peeled off from the glass plate, immersed in a cross-linking solution bath containing water and acetone mixture (30:70) along with 2.5 mL of Con. HCl, 2.5 mL of glutaraldehyde (GA). After allowing for 12 h, take out the membrane from the cross linking bath, and wash with deionized water repeatedly then dry in an oven at 40°C to eliminate the presence of residual acid, if any. The dried MMMs were peeled off and designated as SA-HPC-2, SA-HPC-3 respectively. Membrane thickness was measured by a micrometer screw gauge at different positions on the flat surface area of the membrane and the thicknesses of the membrane prepared were around $35\text{--}40\mu$.

2.3. Pervaporation experiments

Pervaporation (PV) apparatus consists of stirred stainless steel cell through which retentate is circulated to the feed tank. Effective surface area of the membrane in the cell is 28.27 cm^2 with a radius of 3.0 cm and volume capacity of the cell is about 250 cm^3 . Temperature of the feed mixture is maintained constant using a thermostatic water jacket. The Pervaporation (PV) cell is provided with an efficient three-blade stirrer powered by a DC current motor in the feed compartment. Turbulent flows were obtained even at low rotation of the stirrer, i.e., $< 200\text{ rpm}$ speed. Mass transfer limitations due to concentration polarization are negligible. The permeate is collected in a glass container, cooled in a Dewar flask with liquid nitrogen. The vacuum is maintained by a two – stage vacuum pump. The experimental procedure remained the same as reported elsewhere [31]. Weight of the permeate vapors collected in a Dewar flask with liquid nitrogen trap was measured and its composition was determined by measuring its refractive index by comparing it with the standard graph of refractive index Vs. mixture composition of the feed system. The Selectivity, α , of a given membrane was estimated using the following equation [32].

$$\alpha = \left(\frac{Y_A}{1 - Y_A} \right) \left(\frac{1 - X_A}{X_A} \right) \longrightarrow (1)$$

Where X_A is mole fraction of water in feed and Y_A is the mole fraction of water in permeate. The Flux, J ($\text{Kg}/\text{m}^2\text{ h}$), was calculated from the weight of liquid permeated, W (Kg), effective membrane area, A (m^2) and actual measurement time, t (h) as

$$J = \frac{W}{At} \longrightarrow (2)$$

2.4. Membrane Swelling

The swelling experiments on the circularly cut membranes were performed at 30°C gravimetrically [33] in 10, 12.5 and 15 wt. % water-containing feed mixtures. MMMs of Blend samples with compositions ranging from 10 to 15 wt % water at $30^\circ\text{C} \pm 0.5^\circ\text{C}$ in an electronically controlled

incubator (WTB Binder, model BD-53, Tuttlingen, Germany) as per procedures reported previously [34]. To do this, dry weight of the circularly cut (diameter=2.5 cm) disc shaped MMMs of blend membranes were stored in a desiccators over anhydrous calcium chloride maintained at 30°C for about 24h before performing the swelling experiments. This dry weight of the circularly cut (diameter = 2.5cm) MMMs of blend membranes were taken, mass of the soaked samples were measured using a single-pan Adam digital microbalance (model AFP 210L) having a sensitivity of ± 0.01 mg. The swollen membranes were weighed immediately after careful blotting surface to remove the adhered water. The percent degree of swelling (DS) was calculated as

$$\text{Degree of swelling (S) (\%)} = \frac{(W_s - W_d) \times 100}{W_d} \quad \longrightarrow (3)$$

Where W_s and W_d are the mass of the swollen and dry membranes, respectively.

2.5. Fourier transform infrared spectral (FTIR) analysis

FTIR Spectra measurements were recorded in the wavelength region of 4000-400 cm^{-1} under N_2 atmosphere at a scan rate of 21 cm^{-1} using Bomem MB – 3000 (Make :Canada) FTIR spectrometer, equipped with attenuated total reflectance (ATR). About 2mg of the sample was grinded thoroughly with KBr, and pellets were made under a hydraulic pressure of 600 kg/cm^2 .

2.6. Measurement of refractive index:

Refractive index, (N^D) for sodium-D line was measured using the thermostatically controlled Abbe Refractometer (Atago 3T, Japan) with an accuracy of ± 0.001 . Refractometer was fitted with hollow prism casings through which water was circulated. The experimental temperature of the prism casing was observed with a digital display ($\pm 0.01^\circ\text{C}$). The instrument directly gives the values of N^D . Permeate composition was determined by measuring refractive index and comparing it with the established graph of refractive index versus mixture composition.

2.7. Scanning electron microscopy (SEM):

SEM micrographs of the MMMs of SA/HPC blends were obtained under high resolution (Mag: 300X, 5kv) Using JOEL MODEL JSM 840A, Scanning electron microscope (SEM), equipped with phoenix energy dispersive. SEM micrographs were taken at Anna University, Chennai.

2.8. Thermo gravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC):

TGA/DSC curves of MMMs at different compositions were recorded using TA instruments differential scanning calorimeter (Model – SDT Q600, USA). The analysis of the samples was performed at heating rate of 10 $^\circ\text{C}/\text{min}$ under N_2 atmosphere at a purge speed of 100 mL/min .

2.9. X-ray diffraction (XRD)

A Siemens D5000 (Germany) powder X-ray diffractometer was used to study the solid-state morphology of the MMMs

of SA / HPC blend membranes. The X-rays of 1.5406 Å wavelengths were generated by a $\text{Cu K}\alpha$ radiation source. The angle of diffraction (2θ) was varied from 0° to 65° to identify any changes in crystal morphology and intermolecular distances between inter-segmental chains of the polymer.

3. Results and Discussion

3.1. FT-IR analysis:

FT-IR spectra of PWA presented in Figure 1(a) shows four characteristic bands for PWA (Figure 1a) around 1084, 983, 890 and 798 cm^{-1} that are, respectively attributed to (P-O), (W-Ot), (W-Oc-W) and (W-Oe-W) stretching vibrations, where in Ot, Oc and Oe refer to terminal, corner and edge oxygen's, respectively [35]. A strong and broad band appearing at 3400 cm^{-1} corresponds to O–H stretching vibrations of the hydroxyl groups of PWA. The FTIR spectra of MMMs, displayed in Figure 1(b), show prominent peaks at 3410 cm^{-1} , 1615 cm^{-1} and 1416 cm^{-1} , that represent stretching vibrations of O-H, COO-(asymmetric), and COO-(symmetric) respectively. That is assigned to O–H and COO-stretching modes of SA, respectively. Characteristic peaks of saccharide structure of SA/HPC are observed between 1630 cm^{-1} and 1450 cm^{-1} , while the majority of characteristic peaks of Keggin structure have disappeared in the spectra of MMMs of blend membrane, indicating a homogeneous distribution of PWA nanoparticles in the blend polymer matrix. It can be observed that the peak intensity corresponding to –OH around 3410 cm^{-1} increase with increasing filler loading, indicating enhanced hydrophilicity of MMMs of blend membranes.

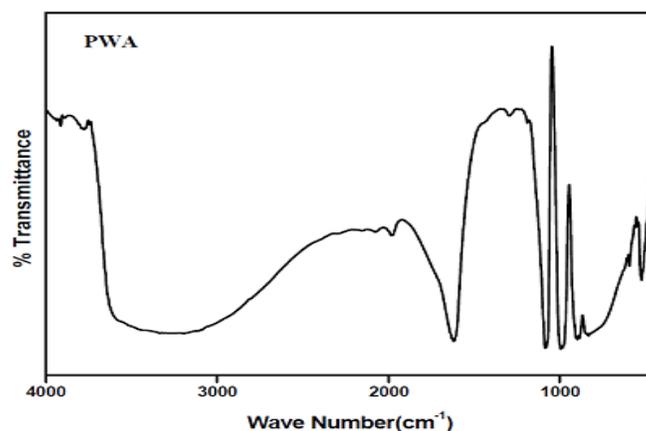


Figure 1(a): FTIR Spectra of Phosphotungstic acid (PWA) showing four characteristic bands.

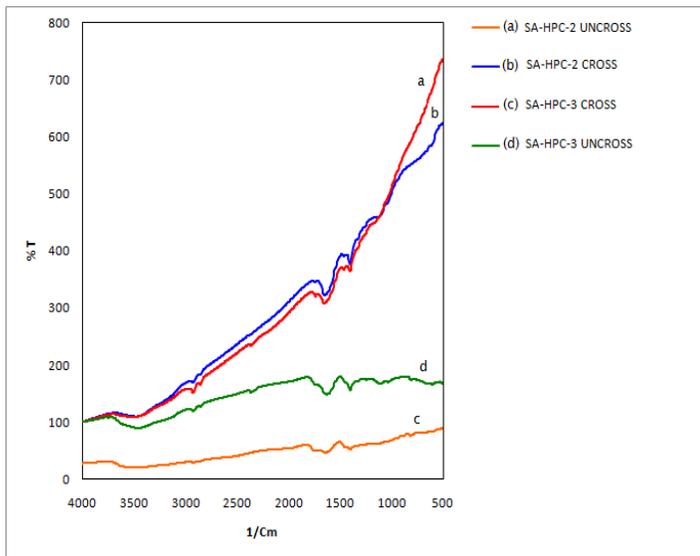


Figure 1(b): FTIR Spectra of MMMs of different composition showing characteristic bands.

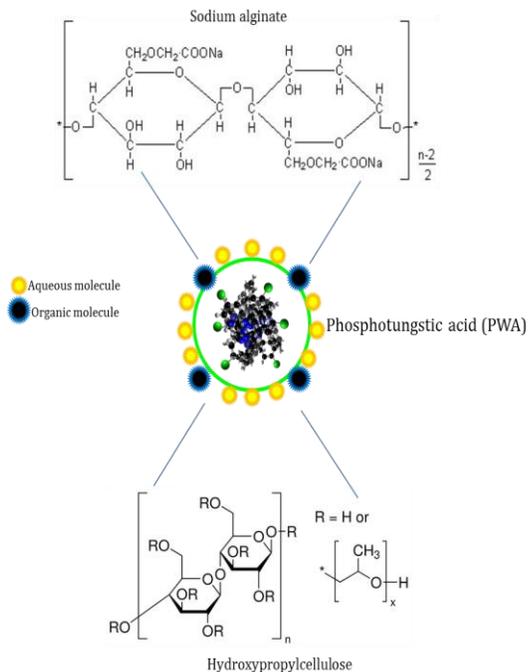


Fig.2. Schematic diagram of the interaction between SA-HPC blend and PWA

3.2. Scanning electron microscopy (SEM):

The SEM images of the MMMs SA-HPC-2 (a), and the cross-sectional image of the MMMs SA-HPC-2 (b), show that the membranes casting were proper as they all depict non-porous structures. Accordingly, such membranes may be considered to be of dense structures, which are essential for Pervaporation studies. The Fig. 3(a) membrane has a thick and dense top layer almost without any pores. A molecular level distribution of PWA particles was observed into MMMs of SA-HPC-2. Typical SEM images MMMs suggests smooth surfaces for all

membranes with no phase separation, in these membranes suggesting a homogenous and more uniform distribution of PWA particles into MMMs of SA-HPC-2 can be seen in the cross-sectional SEM photograph.

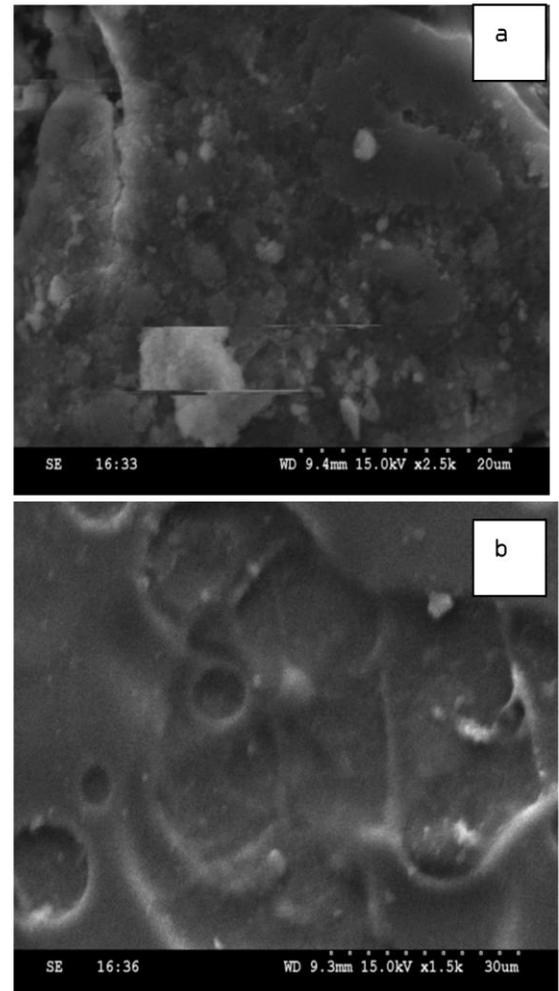


Fig.3. (a) SEM image of MMMs of SA-HPC-2 (b) Cross section image of MMMs of SA-HPC-2.

3.3. Differential Scanning Calorimetry (DSC)

DSC thermograms of the curves displayed in Fig.4 which exhibited a T_g of 62.2°C for the MMMs of SA-HPC-2 blend that was shifted to 72.5°C for SA-HPC-3, respectively after due to intermolecular hydrogen-bonding interactions between the SA/HPC blend and PWA nanoparticles. It can be seen that the T_g values of SA-HPC-2 and SA-HPC-3 are quite identical, suggesting the compatibility between SA/HPC and filler nanoparticles. However, at higher loading as in case of SA-HPC-3, the T_g was shifted to higher value due to micro-phase separation between the organic and inorganic phases that would allow isopropanol to transport across the membrane along with some of the water molecules, thus causing increased permeation flux exhibiting a lower selectivity [38].

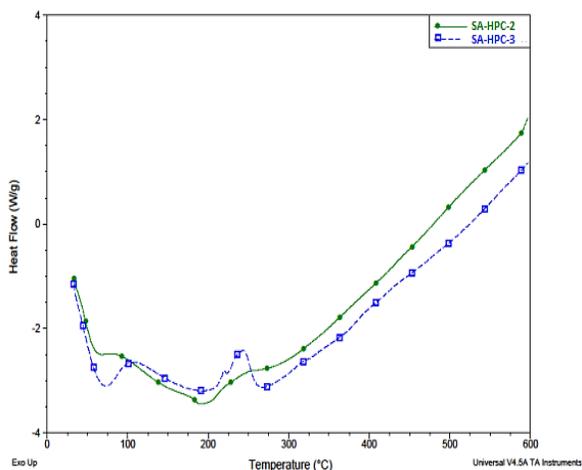


Fig.4. DSC. Thermograms MMMs of the SA-HPC-2 and SA-HPC-3.

3.4. Thermo gravimetric analysis (TGA)

Thermo gravimetric analysis provided quantitative information on the process of weight loss. The thermal stability and degradation behavior of the MMMs of the SA-HPC-2, SA-HPC-3 membranes are shown in Fig.5. From the thermograms, it is clear that under nitrogen flow non-oxidative degradation occurred in two stages for all the membranes. The MMMs of crosslink SA-HPC-3 show the two stage weight loss ranging from 190 to 290 °C and 325 to 500 °C, respectively. The MMMs of SA-HPC-2 on the other hand, shows two step weight loss ranging from 230 to 255 °C and 255 to 325 °C, corresponding to the decomposition of SA-HPC blend and PWA. Thermal degradation studies indicate that MMMs can be effectively used in PV experiment at temperature up to 120 °C, but we did not attempt to investigate up to such high temperature.

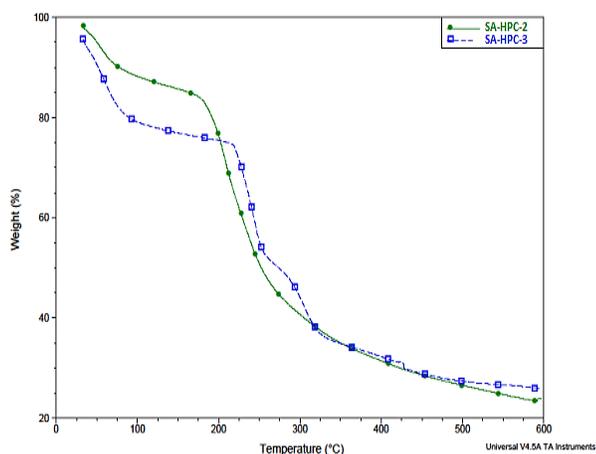


Fig.5. TGA. thermograms of the MMMs of the SA-HPC-2 and SA-HPC-3.

3.5. X-ray diffraction studies (XRD)

X-ray diffractogram of the SA-HPC-2, SA-HPC-3 Cross and uncross linked membranes were shown in Fig.6. From the XRD patterns, it is observed that these is a shift in the position of the peaks of the PWA particles filled Crosslinked mixed matrix blend membranes of SA-HPC

than the uncrosslinked mixed matrix blend membranes of SA-HPC. Further peak intensities for Crosslink SA-HPC-2, SA-HPC-3 mixed matrix blend membranes is more than the uncrosslink SA-HPC-2, SA-HPC-3 mixed matrix blend membranes. The presence of PWA into base polymers SA/HPC blend membranes give wider peaks and low intensity, reflecting increase in the amorphous characteristics of the membranes with tungstate contents. This implies higher selectivity for SA-HPC-3 mixed matrix blend membrane than the SA-HPC-2 mixed matrix blend membranes. For SA-HPC mixed matrix blend membranes, the peaks at $2\theta, 8^\circ, 20^\circ$ and 54° were observed; however, no extra peak could be observed for such membranes as compared to its base polymers, SA/HPC blend membranes. It may be due to small amount of PWA particles present in SA-HPC mixed matrix.

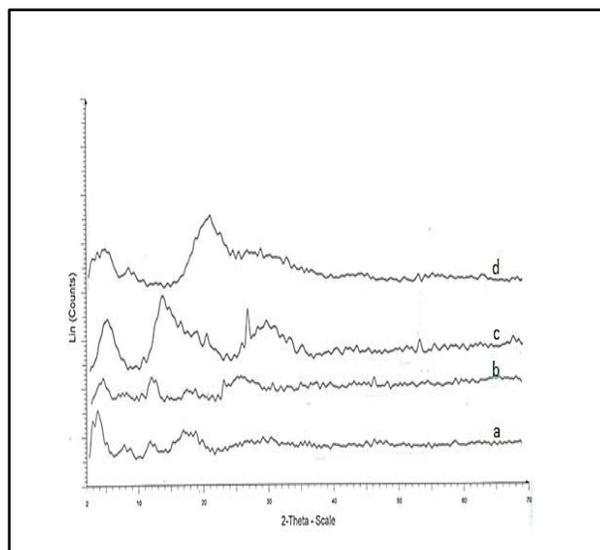


Fig.6. X-RD diffractograms of (a) SA-HPC-2 uncrosslink (b) SA-HPC-2 crosslink (c) SA-HPC-3 crosslink (d)SA-HPC-3 uncrosslink.

4. Membrane Performance

4.1. Swelling Experiments

The degree of swelling obtained from sorption experiments at 30°C for crosslinked pristine blend membrane of SA/HPC and crosslinked MMMs of SA/HPC blends are measured as a function of wt % of water in the feed are displayed in Fig.7, for 10-15.0 wt % water containing feeds. Degree of swelling SA-HPC-3 is almost more than two times higher than that of the pristine SA/HPC blend membrane. Degree of swelling of the membranes displayed in Fig.7. increased with increasing PWA loading as well as with increasing water composition of the feed. This may be due to the hydrophilic nature of PWA nanoparticles, which when added to another hydrophilic MMMs of SA/HPC blend membrane would further increase the degree swelling. This observation is a further evidence of the more water selective nature of the MMMs than isopropanol and even that of SA/HPC. Thus, higher permeation flux and selectivity values are expected for MMMs than pristine SA/HPC. As per solution-diffusion model [36], membrane selectivity is dependent on sorption and diffusion selectivity

that are influenced by the concentration of PWA nanoparticles in the blend matrix. At higher filler loading, both the selectivities increase, reaching the maximum at 0.3 wt.% PWA loading, while for 0.2 wt.% PWA loadings, both sorption and diffusion selectivity curves declined and higher values are observed for MMMs compared to pristine SA/HPC blend membrane. These observations can be attributed to increase hydrophilic-hydrophilic interactions in the MMMs between SA/HPC blend and PWA nanoparticles that are responsible for higher selectivity to water than isopropanol. It is noticed that sorption and diffusion selectivity values for MMMs decrease at higher filler loadings, due to the aggregation of filler nanoparticles. The interaction parameter values systematically decrease for water-polymer in case of MMMs, whereas higher values are observed for isopropanol-polymer system, suggesting lesser interactions. As a result of increased interaction between water and polymer matrix, the water selectivity also increased compared to isopropanol in case of MMMs compared to the pristine SA/HPC blend membrane.

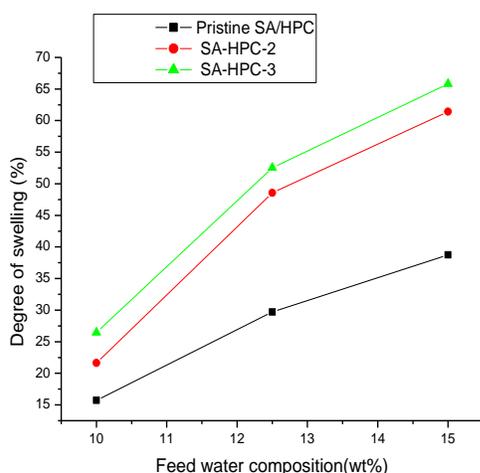


Fig.7. Degree of swelling of Pristine SA/HPC blend and MMMs of SA-HPC-2, SA-HPC-3.

5. Pervaporation studies

5.1. Influence of PWA Loading on PV Performance

Membrane performance was studied by calculating flux and selectivity at different feed compositions of water – isopropanol feed mixtures. The MMMs exhibited higher selectivity than the pristine SA/HPC blend membrane (see Table 1). As can be seen in Table.1 higher selectivity 1314 and a lower selectivity of 58 observed for pristine SA/HPC blend membrane and then the selectivity increased to 1657, respectively for the SA/HPC-3 membrane, while the flux values increased from 0.1884 kg/m²h to 0.3460 kg/m²h. On the other hand, for SA/HPC-2 membranes, selectivity increased to 1542, where as the flux value of 0.3460 kg/m²h are observed, suggesting somewhat lower performances at higher PWA loadings compared to 0.3 wt.% loading. This effect can be explained as due to increased hydrophilic-hydrophilic interactions between PWA particles and the membrane matrix due to the formation intermolecular hydrogen-bonding between SA/HPC blend

and the PWA particles[37](see the interaction model given in Fig.2). These interactions would facilitate higher water transport through the MMMs due to the creation of channels for easy transport of water molecules compared to isopropanol, thus increasing the flux and selectivity values for MMMs. Thus, the present MMMs could dehydrate isopropanol effectively at lower concentration of water. Since water–isopropanol forms an azeotrope at 12.5 wt % of water (a value that is close to 10 wt. %), hence, the present membranes are being useful in separating the azeotropic mixtures.

5.2. Effect of feed water composition

Feed water composition also exerts an effect on the PV performance of MMMs as can be seen from flux and selectivity values given in Table .1 This effect is attributed to polymer plasticization as seen with the pristine SA/HPC blend membrane and variations of the MMMs of SA-HPC blend membranes due to swelling, which would facilitate transport of water molecules from feed to permeate side manifested by hydrophilic–hydrophilic interactions. Pristine SA/HPC blend membranes have higher flux values with a reasonably good selectivity at increasing water concentration of the feed mixture. Flux and selectivity results at 30^o C are presented in Table.1. The flux for pristine SA/HPC blend membrane has increased from 0.1884 to 0.2567 kg/m² h for varying feed concentrations of water from 10 to 15.0 wt.%. As the feed water concentration increases, the selectivity of pristine SA/HPC blend membrane decreases considerably from 1314 to 58. Similar to this observation, wt. % water removed in the permeate also decreased from 99.32 to 89.50. On the other hand, the PV performance of pristine SA/HPC blend membrane was developed by incorporating with PWA (i.e., 0, 0.2, and 0.3 wt %). As the feed water composition increased from 10.0 to 15.0 wt. % with the MMMs, flux values increased with increasing feed water composition from 10.0 to 15.0 wt.%. However, at lower feed water composition (10.0 wt.%), there appears to be a stronger tendency for water molecules to get adsorbed onto the PWA surfaces, but further increase of feed water to 15 wt.% has only declined water selectivity, but with a slight increase in flux. For instance, flux for SA-HPC-2 membrane increased from 0.3253 to 0.3798 Kg/m²h, while for SA-HPC-3 membrane, it increased from 0.3460 to 0.4057 Kg / m²h at an increasing amount of water in the feed from 10.0 to 15.0 wt.%. However, at lower feed water composition (10.0 wt.%), there appears to be a stronger tendency for water molecules to get adsorbed onto the PWA surfaces, but further increase of feed water to 15 wt.% has only declined water selectivity, but with a slight increase in flux. Degree of swelling also has an effect on membrane performance in case of SA-HPC-2, smaller number of water molecules might have been adsorbed, thus lowering the flux values compared to MMMs. With SA-HPC-3 higher loading of PWA might have caused adsorption of large amount of water molecules, thus increasing the flux. Sorption of MMMs is almost twice greater at higher feed water concentration, due to plasticization effect of the membranes as result of which more number of isopropanol molecules along with water molecules would pass through the membrane, resulting in reduced membrane selectivity. The preferential interaction with water molecules causes the membrane to swell,

leading to plasticization and unrestricted and quicker transport of both volatile components through the barrier. On swelling, the polymer chains become more flexible and hence the transport through the membrane becomes easier for both the feed components resulting in high flux [38].

membrane exhibited much higher values of flux and selectivity for water + isopropanol mixture compared to the published data. The present results are almost comparable or even better than some of the previously discovered membranes.

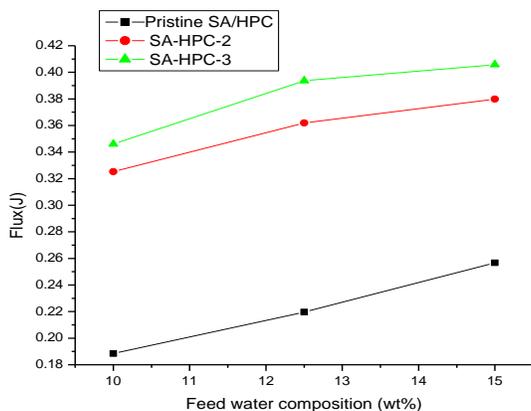


Fig.8. Flux vs. wt. % of water in feed mixture for pristine SA/HPC blend membrane and MMMs of SA-HPC-2, SA-HPC-3.

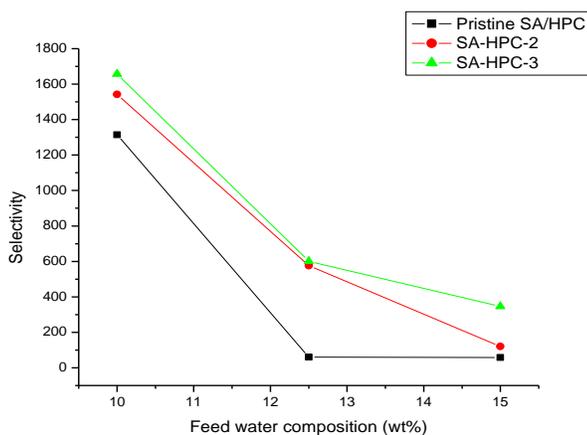


Fig.9: Selectivity vs. wt. % of water in feed mixture for pristine SA/HPC blend membrane and MMMs of SA-HPC-2, SA-HPC-3.

6. Comparison of PV results with literature

In the literature, many types of membranes have been used to study PV dehydration of isopropanol. Table.2. compares flux and selectivity data of the present membranes with those of the literature data. A comparison of all the membranes was made under similar feed conditions and temperature. After incorporating PWA particles into SA/HPC blend membrane, the MMMs properties of SA/HPC blend membrane have greatly improved. It is realized that the performance of the pristine SA/HPC blend membrane is not satisfactory due to larger free volume between the polymer chains. However it is clear that the MMMs property is improved by the incorporation of PWA and hence, the present MMMs of SA-HPC-3 blend

Table. 1.Pervaporation data for feed mixture of water –IPA at 30 ° C.

Wt % of water In feed	Wt% of water in permeate	Flux (J)(Kg/m ² h)	Selectivity (α)
Pristine SA/HPC			
10.0	99.32	0.1888	1314
12.5	89.52	0.2197	60
15.0	89.50	0.2567	58
SA-HPC-2			
10.0	99.42	0.3253	1542
12.5	98.50	0.3619	576
15.0	95.55	0.3798	120
SA-HPC-3			
10.0	99.46	0.3460	1657
12.5	98.85	0.3937	601
15.0	98.41	0.4057	346

Table.2. Comparison of PV performance of the present membranes with literature data

Membrane	Temperature (°C)	wt % of water in feed	Flux (Kg/m ² h)	Selectivity (α)	Ref
SA-HEC-20	30	10	19.21	508	[39]
SA-HEC-5	30	10	16.16	543	[39]
SA-MAS-5	30	20	0.066	1246	[40]
SA-MAS-10	30	30	0.090	1058	[40]
SA-MAS-15	30	30	0.101	1370	[40]
SA-HPC-2	30	10	0.3253	1542	[Present
SA-HPC-3	30	10	0.3460	1657	work]

7. Conclusions

The present study deals with the development of novel type of MMMs from the blend polymers of Sodium alginate (SA) and Hydroxypropylcellulose (HPC) incorporated with hydrophilic PWA nanoparticles for the use in effective isopropanol dehydration. The boost in PV performance of the MMMs is attributed to hydrophilic-hydrophilic interactions between the filler nanoparticles and water. At higher loadings of PWA nanoparticles, aggregation effect may be responsible to reduce water selectivity. The flux and permeate values increased with increasing feed water composition. Sorption data suggests that membrane selectivity is mainly governed by sorption selectivity. With increasing feed water composition the membrane performance exhibited a reduction in selectivity and improvement in flux due to increased swelling. On the whole, the PV separation MMMs of SA-HPC-3 blend membrane is better than pristine SA/HPC membrane as well as those MMMs of SA-HPC-2 blend membranes. This work suggests higher water selective nature for the developed MMMs.

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