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Iron Nanoparticles Blended Polyethersulfone Ultrafiltration Membranes for Enhanced Metal Ion Removal in Wastewater Treatment

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Abstract : A series of iron nanoparticles (modifier) blended polyethersulfone (base polymer) ultrafiltration (UF) membranes was prepared using wet phase inversion method in the blend compositions of 0/100, 1/99, 2/98, 3/97 and 4/96 % respectively. Synthesized membranes were subjected to morphological, thermal stability, UF characterization and metal ion removal studies. Morphological studies using SEM showed the increased number of pores and increased pore size in the blend membranes due to iron nanoparticles addition. Thermal analysis revealed the increased thermal stability of the blend membranes than the pure polymer membrane. UF characterization studies on the prepared membranes clearly indicated the improved hydrophilicity, water uptake and pure water flux with increase in the modifier composition in the membranes. Metal ion rejection studies conducted on these blend membranes showed that the permeate fluxes increased with increase in the modifier composition in the blend membranes, with a small reduction in the metal ion rejection percentage.
Keywords: Ultra filtration, Polyethersulfone, Iron nanoparticles, Membrane blending, Membrane characterization, Metal ion removal.

Introduction & Experimental Procedure:

Ultrafiltration (UF) is one of the rapidly growing technologies for macromolecules separation from solutions especially for metal ion removal from the wastewater. The basic phenomena of ultrafiltration along with its commercial importance have been extensively reported in literature[1,2]. Polyethersulfone (PES) based UF filtration membranes are widely used for membrane synthesis for wastewater treatment[1,2]. However, pure PES membranes suffer from the limitation of lower fluxes. Blending the base PES polymer with several modifiers has resulted in membranes with enhanced ultrafiltration properties[3,4]. Iron nanoparticles (FeN) has been successfully blended with other polymer based membranes resulting in the enhanced features of the respective base membrane[5]. In this current study, a series of UF membranes with PES as base polymer and FeN as modifier have been synthesized in varying compositions. The prepared membranes were subjected to morphological, thermal and UF characterization analysis. Subsequently, the performance of the prepared membranes was studied through metal ion rejection tests and the results are discussed.

PES based asymmetric UF membranes are predominately prepared by wet phase inversion method. Standard procedure of wet phase inversion method for membrane preparation as described in literature[1], was adopted for the membrane synthesis. The cast solution composition for the various membrane blend preparation is 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. Contact angle measurements were done using Goniometer (DGX Digidrop). Pure water flux, measured at different pressures, was determined using the equation, $J_w = [Q / (A \Delta T)]$ where, J_w is permeate flux (lit m^{-2} h^{-1}), Q is quantity of permeate (lit); A is membrane area (m^2), ΔT is sampling time (h). The hydraulic resistance for a given blend membrane was evaluated from the inverse of the slope for the plot between pure water flux (J_w) and transmembrane pressure difference (ΔP). Thermal stability analysis (DSC analysis) for a given blend membrane was carried out using DSC 214 Polyma Instrument to obtain the glass transition temperatures of the prepared membranes. Metal ion rejection percentage was calculated using the equation, $\%SR = [1-(C_p/C_f)]*100$ where, C_p and C_f are metal ion concentrations of permeate stream and feed stream, respectively.

Results & Discussions

Morphology studies on PES – FeN blend membranes showed better porosity in comparison to pure PES membrane. As shown in figure 1, it could be seen that the number of pores as well as the pore size got increased with the FeN addition to the blend membranes.

Figure 1: SEM images of pure and blend membranes

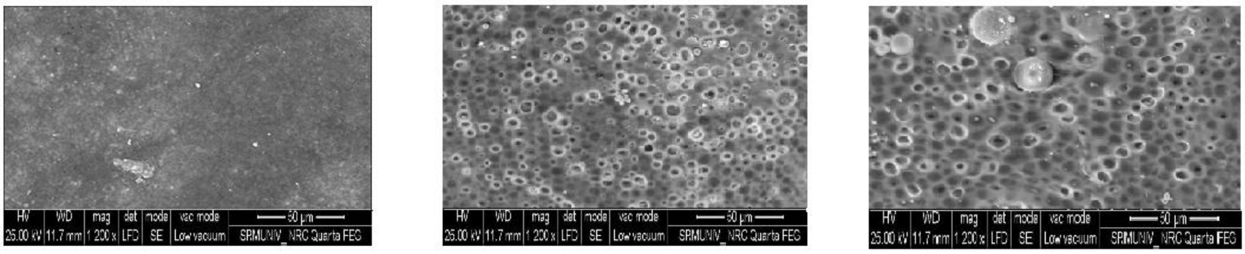

Figure 1 a Figure 1 b Figure 1 c

a) PES (100%) b) PES – FeN (98 / 2%) c) PES – FeN (96 / 4%)

Ultrafiltration and thermal analysis results for the prepared UF membranes are presented in Table 1. Contact angle measurements recorded decreasing values of contact angle with increase in FeN concentration in the blend membranes, revealing the enhanced hydrophilicity with modifier addition. Pure water flux and water uptake increased with increase in FeN concentration in the blend membranes. The hydraulic resistance of the blend membranes recorded a decreasing trend with the increasing modifier concentration. Thermal analysis indicated the improved thermal stability of the blended membranes due to the FeN addition. The glass transition temperature (T_G) of the 96% PES – FeN blend membrane was 47.5% times higher than the pure PES membrane. From above characterization results, it is evident that addition of FeN modifier to PES membrane has increased the UF and thermal characteristics of the blend membrane as compared to the pure PES membrane

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

Membrane Composition		Pure Water flux (lit m^{-2} h^{-1})					Contact Angle (deg)	Membrane Hydraulic Resistance (kPa m^2 h lit^{-1})	Water uptake (%)	Glass Transition Temperature (^oC)
PES (%)	FeN (%)	138 kPa	207 kPa	276 kPa	345 kPa	414 kPa				
100	0	1.7	3.4	3.9	5	6.1	62.22	66.23	55.12	389.21
99	1	3.1	4.5	5.8	7.3	9.3	51	45.45	55.4	485.41
98	2	5.5	8	11.1	13.4	15.1	49.27	28.01	58.53	531.26
97	3	8.4	13.7	16.4	20	24	44.18	18.42	60.86	555.09
96	4	8.8	14	16.8	21	24.7	41.37	17.79	65.34	574.06

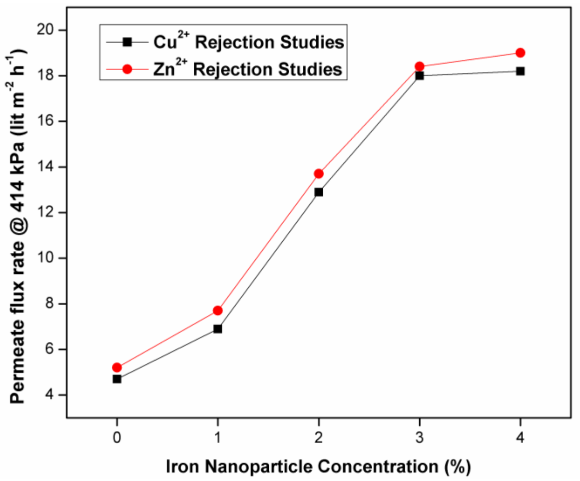

Figure 2: Flux vs FeN Concentration

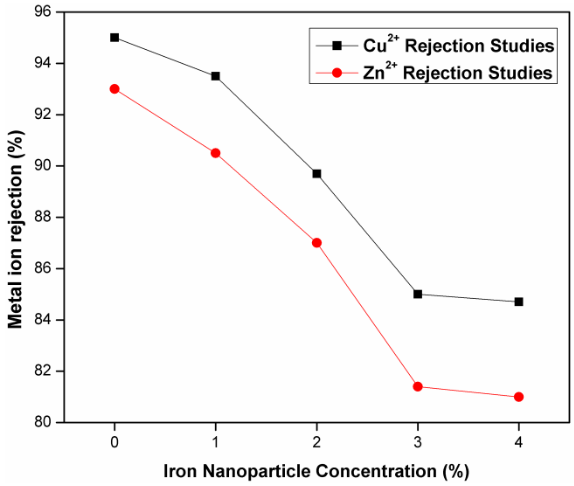

Figure 3: Rejection vs FeN Concentration

All the prepared membranes were subjected to metal ion rejection test to analyze their performance. Results of the metal ion rejection studies (Cu^{2+} and Zn^{2+}) on the pure and the blend membranes are shown in figure 2 and 3. Results of performance tests showed that the blend membranes had an increased flux with a slight decrease in the metal ion rejection percentage as compared to that of the performance of pure PES membrane. The reason for this behavior could be attributed to the increased pore size as well as the increased number of pores in the blend membrane due to the FeN addition.

Conclusions

A novel series of iron nanoparticles (FeN) blended polyethersulfone (PES) ultrafiltration membrane was synthesized in varying compositions and subjected to membrane characterization analysis. Membrane characterization studies on the prepared membranes showed the enhanced pores statistics, water permeability, hydrophilicity and thermal strength with the addition of FeN modifier to the polymer membrane. Metal ion rejection tests were conducted on the pure PES as well as blend membranes. Results clearly indicated that the blend membranes recorded an increased flux (with increase in FeN concentration) with a slight decrease in the rejection percentage of the metal ions as compared to that of the pure PES membrane. Studies clearly support that FeN blended PES membranes are promising candidates for metal ion separation applications which require higher permeate fluxes with an agreeable rejection percentage.

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