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Removal of Phenolic Compound from Bangalore Nelagadaranahalli Lake Using PS-PEI Blend Membranes

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ABSTRACT

Membrane technology plays vital role in water purification. India losing many lakes due to either encroachment or pollution. Lakes supposed to be water source instead it is now becoming waste dump yard. Addressing these problems there is great need to identify sustainable methods of purifying lake water at lower cost and with less energy, while at the same time minimizing the use of chemicals and impact on the environment. We developed the cross-membrane filtration technique to remove phenolic compound from Nelagadaranahalli lake, Peenya industrial area, Bangalore, Karnataka, India.

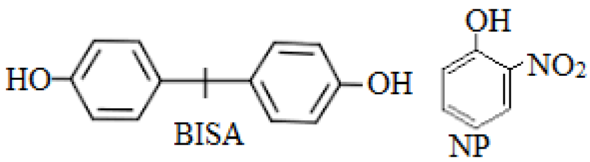
This research work carried out in our lab has successfully demonstrated the removal of phenolic compound from contaminated water lake, utilizing Polyetherimide (PEI) - Polysulfone (PS) membrane. This research work describes the methodology for preparation of membranes by 'diffusion induced phase separation' (DIPS) method. As per WHO standard the optimal phenol content in drinking water must be in the range of 1.0 micro g/L hence the prepared membrane performance has been investigated in terms of important parameters like pure water permeability, and percentage rejection of phenol compound.

Keywords: PS - PEI membrane, cross flow filtration, phenolic compound, removal efficiency

INTRODUCTION

Water is the driving force of life (Chaplin Martin 2001). It is impossible to survive plants, animals, and humans without water. Though planet earth has 70% of water, only around 3% are fresh. Water can exist in the form of oceans, lakes, and rivers. Due to excessive human activity and rapid industrialization putting great load of pollutant to the lakes. In metropolitan area, lakes can play dynamic role in managing flood. It can also act as water storage reservoir, which may be used during draught. Lake ecosystem useful in restocking groundwater level, improving water quality of downstream watercourses and preserving the biodiversity and habitation of the surrounding area (Hakanson L 2005). Lake supposed to be excellent source of water resource becoming hazardous spreading entity.

Due to many reasons, lakes may acquire phenolic impurities (Seth R et al 2013), these compounds are carcinogenic if these compounds are released into waterbodies, it will adversely affect humans, animals and even microorganisms. Our research work mainly focuses removal of two phenolic compound, nitrophenol (NP) which can cause pneumoconiosis and bisphenol A (BISA) which can cause neurological disorder.



There are different methods for the removal of phenol from effluents. Phenol can be removed by using Ozone (Kadir,T and Suheyla U et al 2008), activated carbon (Nuhu, D. M. et al 2017) and by RO (reverse osmosis) (Guido, B. et al. 2008) . Removal of phenol by ozone treatment is very expensive and not very effective. Use of activated carbon in removing the phenol is very labour intensive. Hence, the most pragmatic way of approach is by reverse osmosis, i.e., by using a semi-permeable membrane.

EXPERIMENTAL

Materials and instruments

Polysulfone (PS) having molecular weight of 35,000, Polyetherimide (PEI) having granular, 3mm size, Reagent grade N-methyl pyrrolidone (NMP), was obtained from Merck-India and was used without any further purification. ATR -FTIR analyzed using NEXUS 6700 Thermo Nicolet. SEM images of the newly prepared membranes were recorded on Jeol JSM-84. The permeation experiments were performed by a self-fabricated flux/rejection checking apparatus with membrane disk has an effective area of 10 cm^2. VCA-Optima (AST products Inc., MA, USA) were used to measure contact angle of the membranes. HPLC unit used to determine phenolic component of the feed and permeate sample.

Sampling

Sample water collected from Nelagadaranahalli lake, Bangalore, Peenya industrial area, Karnataka, India with geographic details 13^{0}1′14″N 77^{0}29′49″E. Water collected under 1 meter to the level of the surface water and large particles from collected water sample removed by filtration (Ramos, R. L. 2021). Lake photograph is shown in Fig 1

Fig. 1. Nelagadaranahalli lake photograph

Preparation of PS - PEI blend membrane

Solutions containing different wt. % of PS and PEI in 9.5 mL of NMP were prepared. The composition of the material used, shown in Table 1. The solution was stirred for 24 hours at 60 ºC for completion of dissolution followed by sonication for 30 minutes. When solution turn highly viscous, it was carefully casted over glass plate using doctor knife. The membranes were separated by dipping the glass plates in distilled water. Further separated membranes cured by dipped it in distilled water for 24 hours (Hegde, C. et al 2014). Preparation route for the membranes has been presented in Fig.2.

Table. 1. Solutions containing different wt. % of PS and PEI.

Membrane Code	Wt % (PS)	Wt % (PEI)
CH1	95	05
CH2	85	15
CH3	75	25
CH4	65	35

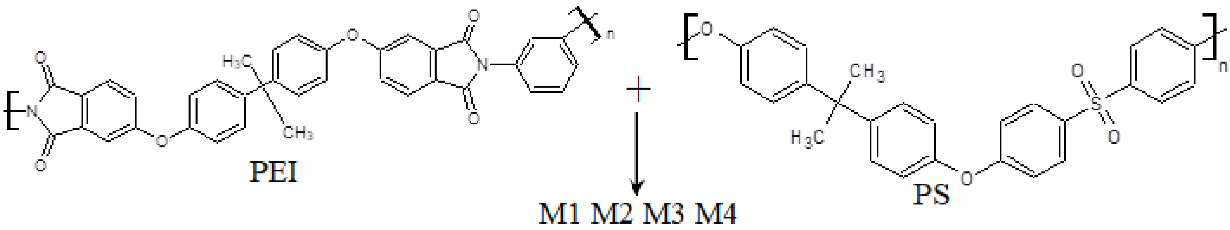


Fig. 2. Preparation of membranes

Flux and rejection study

Phenol rection is studied using lab made, self-fabricated flux /rejection equipment. The schematic picture of the process represented in Fig 3. The Flux, F (L/m^2 h), rate was calculated using following equation.

$$F = W / A\,t$$

Where 'W' (L) is the total volume of the water or solution permeated during the experiment, A (m^2) is the membrane area, and 't' (h) is the operation time. Rejection, R, is calculated using equation 2,

R= (1-concentrate permeates / concentrate feed)

Removal efficiency (%), of phenolic compound can be calculated using equation

$$\text{Removal efficiency (\%)} = \frac{\text{Concentrate of feed - Concentrate of permeate}}{\text{Concentrate of feed}} \times 100$$

The collected sample taken in a feed tank and was pumped into the membrane module. The pressure difference between the feed inlet and the outlet during operation was adjusted from 1 to 8 Bar. The rate of the permeate stream was measured by a rotameter and a gauged cylinder and rejection (%) of phenolic compound was studied by quantitative measurement of phenols using technique of HPLC (Hegde, C. et al. 2011).

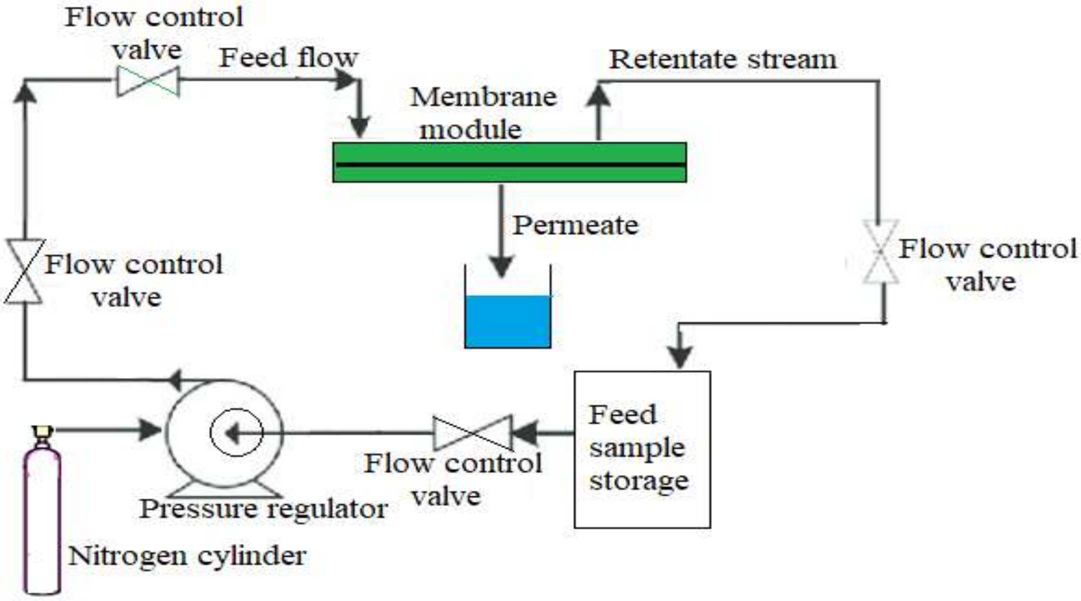


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Fig. 3. Schematic representation of the flux/rejection process.

RESULT AND DISCUSSION

ATR - FTIR study

Formation of blend membrane confirmed by ATR-FTIR. Prepared membranes dried and were analyzed for IR spectrum. Attenuated total reflectance Fourier transform Infrared spectroscopy (ATR-FTIR) used to identify characteristic stretching frequencies of the membranes. The analyses were carried out using a NEXUS 6700 Thermo Nicolet Fourier transform infrared spectrometer in a wave number range from 4000 to 600/ cm with a scan rate of 0.63 cm/s and the spectral resolution was of 4/cm having ATR crystal made from diamond. Fig 4, exhibits characteristic imide group absorptions at 1780 cm^{-1}, 1355 cm^{-1} (C-N stretching), 1234 cm^{-1} (aromatic ether C-O-C), 3600 - 3200 cm^{-1} for O-H stretching vibrations and 1170 cm^{-1} for asymmetric O═S═O stretching of sulfonate (Belfer, S. 2000).

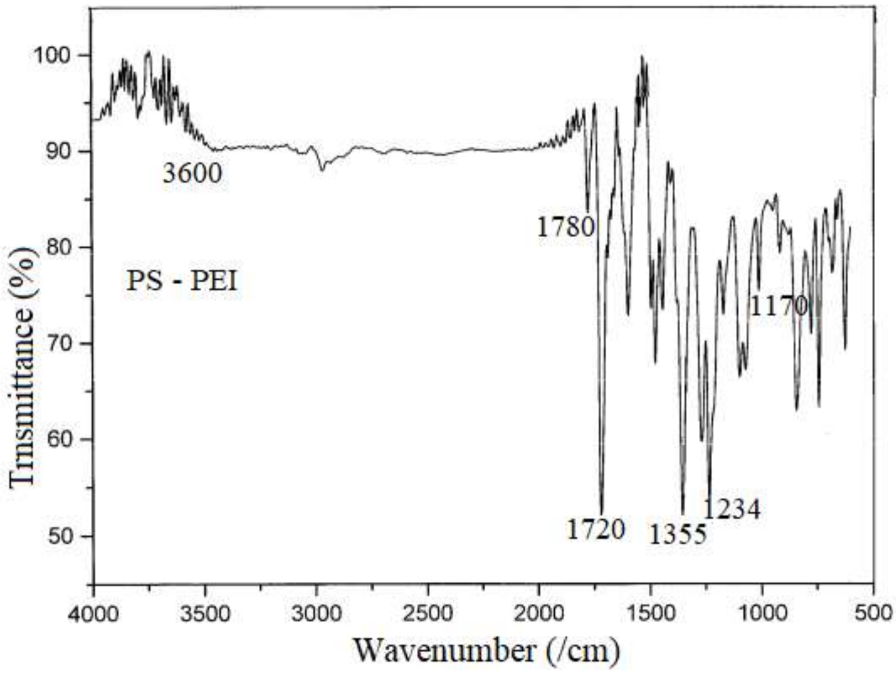

Fig. 4. IR spectrum of the membrane

Contact angle measurements

The wettability of the membranes was determined using contact angle measurements by sessile drop method (Kwok, D. Y. et al. 1997). The results of contact angle measurements are summarized in Table 2, Usually, lower the contact angle more is the hydrophilicity of the material, and the hydrophilicity of membranes has a positive effect on the flux.

Table. 2. Contact angle measurements of different membranes.

Membrane Code	Before alkali treatment Contact angle in degree
CH1	78±2
CH2	73±2
CH3	69±2
CH4	68±2

Morphology of membrane

Morphology of the prepared membranes studied with the help of scanning electron microscope (SEM). Fig 5 represents cross section and surface image of the membrane (Munari, S. et al. 1985). Pores are not perfectly cylindrical may cause breakdown of the membrane at high pressure. From the image finger like projections eases flux rate.

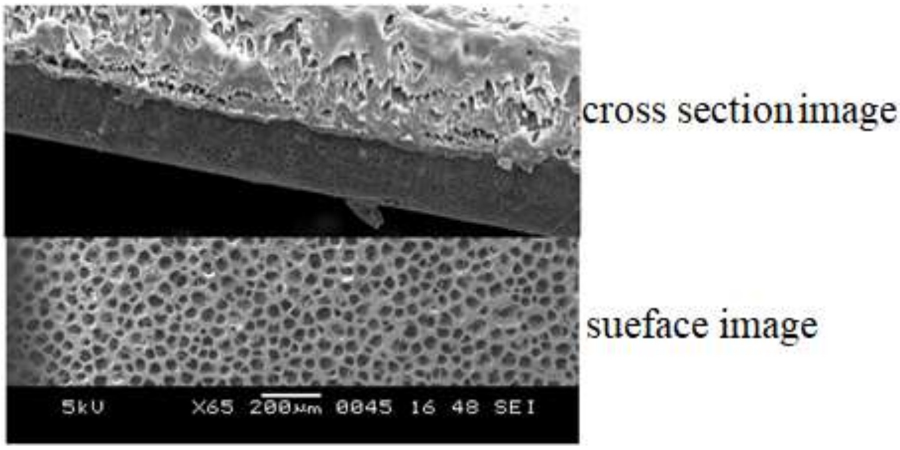

Fig.5 Cross section and surface image of the membrane

Phenol compound rejection and water quality check

For this research work, we have collected 300 liter of water sample from Nelagadaranahalli lake. Lake being situated in Peenya, Bangalore, India industrial area and many contaminated pollutants discharge from various industry reaches to lake. It is sad part of Bangalore, which is capital of Karnataka, India once known as city of lakes now left with only few lakes and those remaining lakes, are ether encroached or highly contaminated. After going through water analysis, we can detect phenolic compound namely, Nitrophenol (NP) and Bisphenol A (BISA). The presence of this phenolic compound may be result of discharge of dyes, rubber products, pharmaceutical waste, epoxy resin, household material like soaps, paints, perfumes and varnish removers, textiles effluent, etc. However, the original source of above-mentioned phenolic compound only can be ascertained after detailed study of land use and occupation studies.

Physicochemical characterization of collected water and permeate water summarized in Table 3.

It is observed that feed sample have high concentration of phenolic compound. After passing through membrane module collected permeate sample show improved quality of water. The permeate water quality values shown in Table 3 are at applied pressure 8 bar and with membrane CH1. Our lab prepared membranes and cross flow equipment successfully removed 84% of NP and 92% of BISA (Laura, G. C. V. et al. 2016).

Flux (l/m^2h) and percentage of rejection experiment carried out using lab made flux-rejection equipment (Fig. 6) at 1- 8 bar applied pressure. With increase in applied pressure membrane show increased rejection and flux rate. The values of flux and rejection percentage for all prepared membranes are shown in Fig 7 - 10. CH1 shows better compatibility and performance for the removal of impurities.

Table .3 Characteristic of feed and permeate water sample

Parameter	Feed sample	BIS standard for surface water	Retention time (min)	Permeate sample	Removal Efficiency (%)
pH	8 - 8.8	8.7	-	7.9	
Conductivity (µS/cm)	12300	1200	-	97	
TDS (ppm)	8200	700	-	600	
BOD (ppm)	43	5	-	21	
COD (ppm)	87	30	-	45	
Total hardness (mg/L)	880	200	-	190	
Chlorides (mg/L)	898	250	-	160	
NP (µg/L)	120	1.0 µ g/L (WHO)	11	19 µg/L	84
BISA (µg/L)	136	1.0 µ g/L (WHO)	37	10 µg/L	92

Fig. 6. Digital photograph of lab made flux- rejection equipment

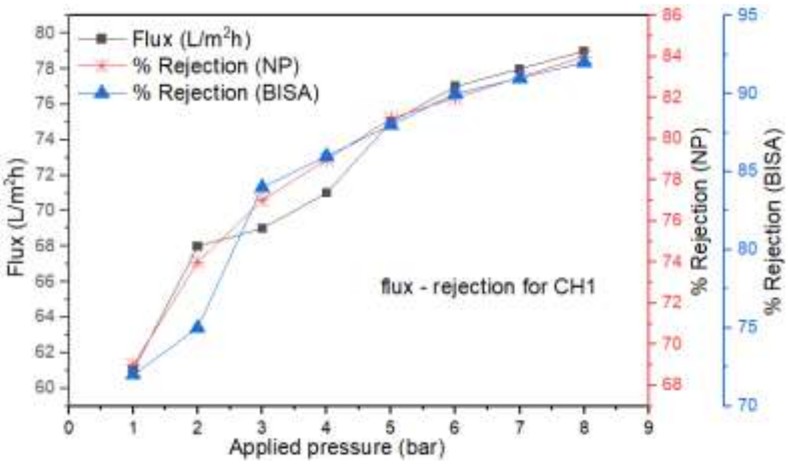

Fig. 7. Flux - rejection study using CH1 membrane

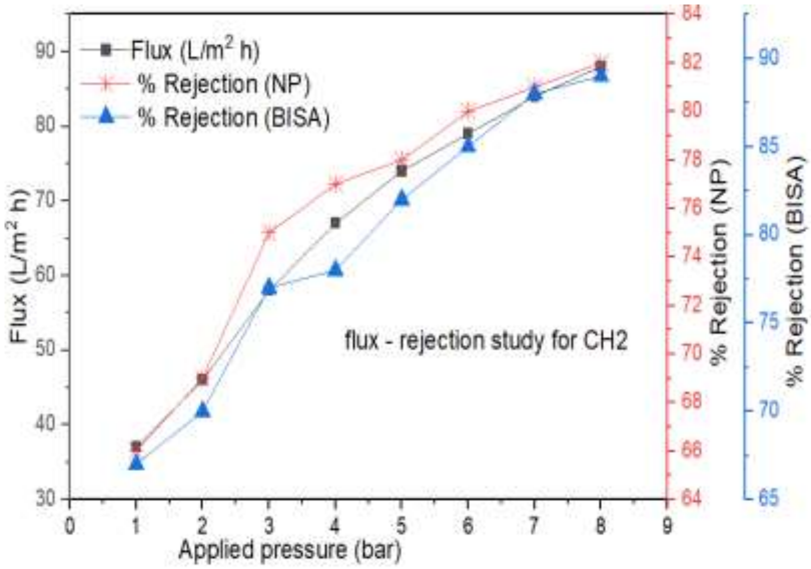

Fig. 8. Flux - rejection study using CH2 membrane

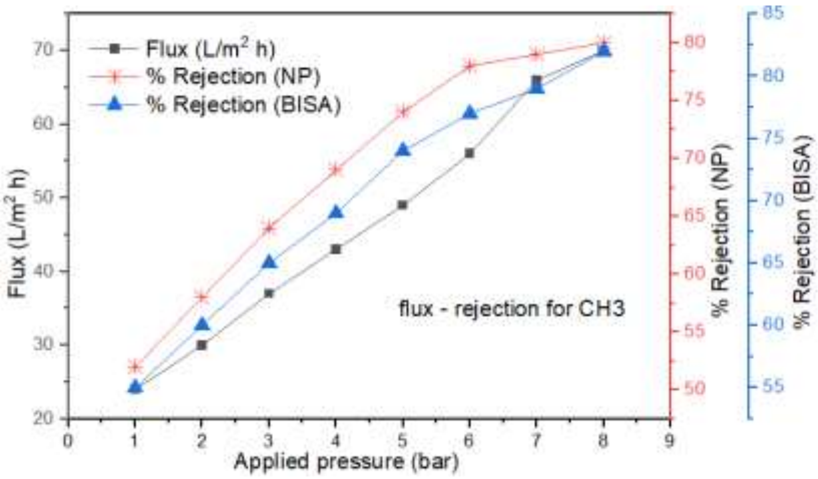

Fig. 9. Flux -rejection study using CH3 membrane

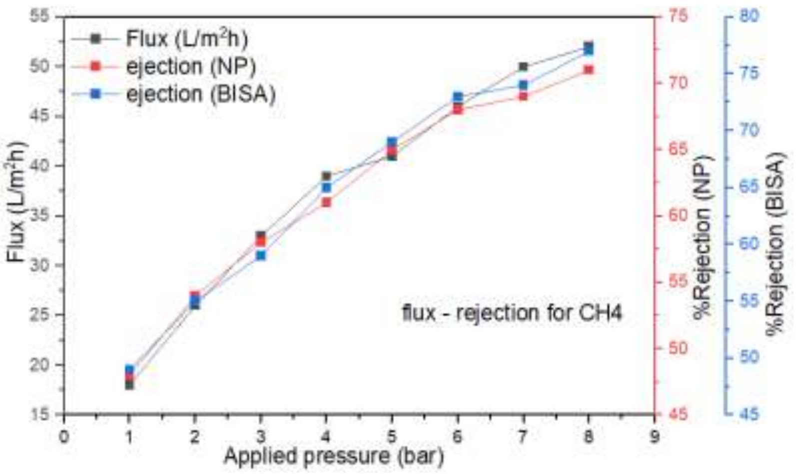

Fig. 10. Flux- rejection study using CH4 membrane

Determination of phenolic compounds (Kumar, B et al. 2014) at microgram level was done using Agilent Technology Inc., Santa Clara, CA, USA a high performance liquid chromatograph (HPLC), along with necessary accessories with operating condition listed in Table 4.

Table 4. Operating condition for the analysis of phenolic compounds

Injecting dose	15µL
Analyte column	5.6×12.5 mm, 5 µm diameter particle size
Mobile phase composition	0.1% o-phosphoric acid in HPLC water& in methanol
Scouting gradient	15 to 95% B in 30 minutes
Mobile phase flow rate	0.9 mL/min
Temperature	25±1°C
Detector	Diode array detector (DAD), 280 nm

CONCLUSION

We successfully prepared membranes from PS and PEI using DIPS method. Self-fabricated flux - rejection equipment used to remove phenolic compounds. The phenolic compounds were found in Nelagadaranahalli lake. The source of origin of phenolic contamination probably from surrounding industry of the lake. Using this membrane cross flow filtration unit, we removed 84% of NP and 92% BISA. Along with removal of phenolic compound, permeate water shows great reduction in the other associated pollutant present in water. This research work importantly suggests two factors of recommendation (i) present prepared membrane is excellent candidate for phenol removal from water (ii) studied Nelagadaranahalli lake, is highly contaminated and concerned authority need to give immediate attention for adopting corrective measure.

Declaration of competing interest

There is no competing interest to declare.

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