Volume : 5 | Issue : 6 | June 2016 • ISSN No 2277 - 8179 | IF : 3.508 | IC Value : 69.48

Research Paper

Eco Friendly Membrane Preparation and Its Application Studies

Chemistry

KEYWORDS : Green membrane, Filtration, Physico-chemical parameters.

Karunambika.v	Deperament of Chemistry,Avinashilingam Inistitute for Home science and Higher Education for Women, Coimbatore,Tamil Nadu, India.
Anitha.S	Deperament of Chemistry,Avinashilingam Inistitute for Home science and Higher Education for Women, Coimbatore,Tamil Nadu, India.
Thamaraiselvi.J	Deperament of Chemistry,Avinashilingam Inistitute for Home science and Higher Education for Women, Coimbatore,Tamil Nadu, India.

ABSTRACT

The aim of the study is to prepare the green membrane by low cost and eco friendly method. The prepared membrane has been characterized by using FT-IR, SEM & TGA analysis. The green membrane has been applied to salty water filtration. The filtrated water is used to study the physico-chemical parameters. Most of the parameters correlated with the value prescribed by WHO.

Introduction

An increasing scarcity in fresh water sources fuelled a push towards alternative resources such as ocean water. In the 1970, exploration began into using membranes for water desalination. Implementation of membranes for water treatment has progressed using more advanced membranes made from new materials and employed in various configurations1. Reverse osmosis is nowadays the most extended technology for desalination globally. Besides, it has become a viable technology for wastewater reclamation2. These advances mainly include developments in membrane properties and module design, process design, feed pre-treatment, energy recovery devices, and operational strategies focused in energy consumption reductions3,4. Membrane separation processes, an energy saving and high- efficiency technology, have been widely used for separation tasks in the chemicals, food and biotechnological industries5,6. Cellulose acetate(CA) as a membrane material has found extensive commercial application, because of its relatively low cost, high selectivity, high permeability and easiness of controlling pore size7,8. Various tribes use the different parts of the vetiveru and nannari for many of their ailments such as mouth ulcer, fever, boil, epilepsy, burn, snakebite, scorpion sting, rheumatism, fever, headache, etc9. The preservation of water resources to prevent their pollution by toxic elements has become one of the most important challenges for the human race due to the exuberant growth of textile, leather, surface treatment, mining, motorcar and chemical industries which generate toxic heavy metals are released into the environment. Heavy metals are dangerous due to bioaccumulation10. The increased concerns in the environment, health and the strengthened regulations demand more strict treatment of water and wastewater. Traditional methods for elimination, concentration and or recovery of heavy metals such as precipitation, ion exchange, electrodepostion, crystallization, evaporation, liquid-liquid extraction, etc., have great disadvantages by operating in a succession of steps of heterogeneous reactions, or distribution of substances between different phases which usually require a lengthy operating period11.

MATERIALS AND METHODS

Chemicals required

Celluloseacetate (AR Spectrum chemical reagents), Dimethylacetamide (Finar chemicals limited), Nannari powder, Vetiveru powder (purchased from market), Diethyl succinate(Loba chemie), Ammonium chloride and EDTA(LR Sd fine-chem limited), Eriochrome black-T indicator(LR Finar chemicals limited), potassium dichromate (0.250M), Standard ferrous ammonium sulphate (FAS) (0.25N), conc sulphuric acid,

Preparation of membrane -1

About 1g of cellulose acetate and 50mg of nannari powder was mixed with about 6ml of dimethyl acetamide and it was stirred in mechanical stirrer for about half an hour with a minimum heat of about 30 then it was cooled for 2 minutes and was poured in a flat tile then after 10 minutes the tile was then immersed in water and then the formed membrane was peeled off and then dried for half an hour at room temperature in open air atmosphere. The membrane thickness was found to be 0.53mm.

Preparation of membrane-2

1g of cellulose acetate was mixed with 6ml of dimethyl acetamide followed by 50mg of vetiveru powder and then it was subjected to vigorous stirring for 40mins using a magnetic stirrer at 30oc.The solution was completely dissolved by stirring and then coated with flat tile. Then the coated solution was immersed into water for 2 to 3 mins. Afterwards membrane were peeled out and then dried for half an hour at room temperature in open air atmosphere. The membrane thickness was found to be 0.55mm.

Preparation of membrane-3

1g of cellulose acetate was mixed with 6ml of diethyl succinate (biosolvent) followed by vigorous stirring with the help of magnetic stirrer at 25oc. After 40mins the solution was completely dissolved and then coated with flat tile. Then the coated solution was immersed into water for 5mins.Afterwards membrane were peeled out and then dried for half an hour at room temperature in open air atmosphere. The membrane thickness was found to be 0.76mm.

Characterization of membranes:

The prepared membrane was characterized by the following techniques.

Compaction

The thickness of the cast membrane was measured using WIRA Digital thickness tester(WIRA Insturment, UK). The thickness of the membrane-1 used in this study was 0.53±0.2mm. The prepared membrane were cut into effec-

Volume : 5 | Issue : 6 | June 2016 • ISSN No 2277 - 8179 | IF : 3.508 | IC Value : 69.48

tive membrane area 55.3896 cm2 and it was initially pressured with distilled water at 250mmHg for 2min 38sec The thickness of the membrane-2 used in this study was 0.55±0.2mm. The prepared membrane were cut into effective membrane area 38.465 cm2 and it was initially pressured with distilled water at 250mmHg for 2min 45sec. The thickness of the membrane-3 used in this study was 0.76mm. The prepared membrane were cut into effective membrane area 38.465 cm2 and it was initially pressured with distilled water at 250mmHg for 2min 45sec. These pre-pressurized membranes were used in subsequent water filtration process.

Pure water reflux:
Membranes after compaction were subjected to pure water flux studies at a trans-membrane pressure of 250mm/Hg. The pure water flux is determined by using the formula

$$J_W = Q/A\Delta V \quad \rightarrow \quad (1)$$

Where, JW-water flux (ml/cm2min)
Q-quality of water permeate (l)
A-Membrane area (m2)
T-the sampling time (hours)

Water uptake:
Percent water content of the membrane was obtained after soaking the membrane in water for 24hrs and the membranes were weighed followed by mapping it with filter paper. The wet membrane was placed in opened air for 1hr and the dry weights of the membranes were determined. From the wet and dry weights, percentage water content was determined by

$$\%\text{Water content} = \text{wet sample weight} - \text{Dry sample weight} / \text{wet sample weight} \times 100 \rightarrow \quad (2)$$

FT-IR Analysis:
The membrane structure of the prepared membranes was characterised by using FT-IR (Model IR Affinity-1)

SEM Analysis:
The surface morphology of the prepared membranes was viewed through scanning electron microscope studies. (SCANNING ELECTRON MICROSCOPY XL 20 PHILIPS).

TGA Analysis:
Using thermo gravimetric analysis the weight loss of the membranes was found out.(EXSTAR SII TG/DTA6300).

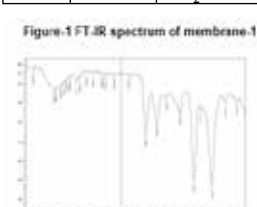
Water filtration by membranes:
The water was filtered using carbon rod(ht-2.5cm & width-0.2cm) covered with the prepared membranes. The sample water was added drop wise to it so the water is filtered through the membranes. The filtered water was then collected and then analysed the physico-chemical parameters.

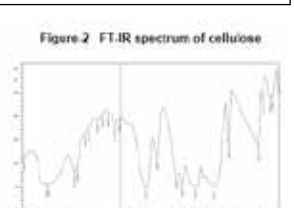
RESULTS AND DISCUSSION

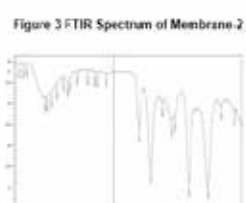
FT-IR spectrum of membrane-1
The peak corresponding to 2376.30, 1743.65 and 902.69 is found to be common peak for prepared membrane and cellulose acetate. The peak at 2376.30, indicates -CC or N-H streaching. The peak at 1743.65 indicates -C=O (ester) (carboxylicacid)(ketone) and for 902.69 it indicate C-H(bending) (strong).The additional peak found for membrane-1 indicated in table -1 and the membrane structure is shown in figure-1.

Table -1
FT-IR Peaks of membrane-1 compared to cellulose acetate

S.No	Frequency (cm^{-1})	Stretching
1	3834.49	O-H
2	3394.72	N-H(Medium)(primary amines have two bands; secondary have one band, often very weak. O-H(alcohol/phenol)(free)(strong,broad).
3	3340.71	O-H(streach,free)(strong band) N-H(medium)(primary amine have two bands; secondary have one band, often very weak)
4	3255.84	O-H(H-bonded)(strong,band) (alcohol),(dimer)
5	3194.12	O-H (dimer)(COOH) N-H(ammonium ion)(broad peak)
6	3132.40	N-H(ammonium ion)(broad peak) O-H(dimer)(broad)
7	3078.39	O-H(dimer)(broad), C-H(aromatic rings)
8	2924.09	C-H(alkane)(strong) O-H(dimer)(broad)(COOH)
9	2854.65	C-H(alkane)(strong), O-H(carboxylic acid), N-H(ammonium ion)(multiple broad peak)
10	2723.49	N-H(ammonium ion), (multiple broad peak), O-H(carboxylic acid)
11	2584.61	N-H(ammonium ion) (multiple broad peak)
12	2407.16	N-H(ammonium ion),(multiple broad peak)
13	2314.58	O-H
14	2144.84	CN(Nitrile)(sharp),N=C=O,C=C=O CC(alkynes),N=C=S,N=C=N.
15	1913.39	C-H(phenyl ring substitution)(overtones)
16	1620.21	$N-H_2$(scissoring)(primary amine) C=C(aromatic bending)
17	1519.91	C=C(aromatic bending) N-H(amine) NO_2(asymmetrical)
18	1373.32	C-H(alkalenes),(scissoring and bending) C-F(alkyl halide)(strong) NO_2(symmetrical)
19	1234.44	C-F(stretch),C-O(ether) N-H(primary amine)(strong band)
20	1041.56	C-N(amine),C-O(ether),N-H(primary amine)(strong band)
21	779.24	CH_2(rocking)







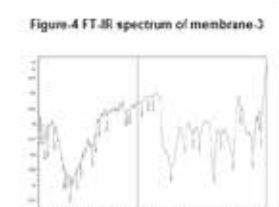


Table-2 - FTIR Spectrum of Membrane-2

S.N0	Frequency(cm^{-1})	Stretching
1	3911.64	X-H(Halogen groups)
2	3834.49	N-H(Amines)
3	3765.05	N-H(Amines)
4	3379.29	O-H(H-bonded)(stretch free strong) (alcohol phenol) N-H(Primary amines)
5	3340.71	O-H (stretch free),(strong bond) N-H(primary amines)
6	3263.56	N-H(primary amines) O-H(stretch free),(strong bond)
7	3155.54	N-H(primary amines), C-H(Alkene),(strong)
8	3024.38	C-H(alkene)(strong) O-H(dimer)(broad) COOH(alcohol-phenol)
9	2924.09	C-H(alkane)(strong), O-H(dimer),(COOH),(broad)
10	2877.79	C-H(Alkane),(strong) O-H(Dimer)(broad)(COOH)
11	2738.32	C-H(Alkane)(strong), O-H(broad)(COOH)
12	2538.32	N-H(ammonium ion),(multiple broad peak) O-H(broad)(COOH)
13	2376.30	C=C(Alkenes)
14	2322.29	C≡C (Alkynes)
15	2152.56	C≡C(Alkynes), N=C=O,N=C=S,N=C=N,C=C=O(isocynates,isothiocynates,dimide,ketones)
16	1620.21	C=C(aromatic bending) N-H(primary amine) C-H(Phenyl ring)(substitution overtones)
17	1504.48	C=C(Aromatic bending) NO_2(asymmetrical stretch)
18	1404.18	C=C(Aromatic bending,medium-weak) CH_2(Bending) C-H(Alkanes)
19	1373.32	C-H(Alkanes,Scissoring and bending) C-F(alkyl halide,strong) NO_2(Nitrocompounds,symmetrical) CH_2(rocking)
20	1234.44	C-F(Alkyl halide) C-N(Medium-weak) C-0(Ether,weak)
21	1041.56	C-N(Amine) C-O(Ether) N-H(Primary amine)(strong,broad)
22	171.53	O-H(Stretch,free)

FT-IR spectrum of membrane-3:

The peak corresponding to 1381.03 is found to be common peak for membrane(II) and cellulose acetate. The peak for 1381.03 indicate C-F (Alkyl halide),C-H(Alkane,bending),N-O(Nitro, strong band).

The additional peak found for membrane-3 are indicated in table- 3

Table 3 FTIR Spectrum of Membrane-3

S.N0	Frequency(cm^{-1})	Stretching
1	3990.51	X-H(Halogen groups)
2	3957.93	X-H(Halogen groups)
3	3888.49	O-H(H-bonded)(stretch free strong) (alcohol phenol)
4	3826.77	O-H(H-bonded)(stretch free strong) (alcohol phenol)
5	3703.33	N-H(amide)
6	3479.58	N-H(primary amines) O-H(alcohol)(phenol) C=0(Aldehyde,ester,ketone,carboxylic acid)
7	3379.29	N-H(primary amines), C=0(Aldehyde,ester,ketone,carboxylic acid) C-H(Alkane) O-H(alcohol,phenol)
8	3240.41	C=0(Aldehyde,ester,ketone,carboxylic acid) O-H(Alcohol,phenol)
9	3163.26	C=0(Aldehyde,ester,ketone,carboxylic acid) O-H(Alcohol,phenol)
10	2924.09	C-H(Alkane),(strong) O-H(Carboxylic acid)
11	2854.65	C-H(Alkane)(strong), O-H(broad)(COOH)
12	2785.21	O-H(Carboxylic acid)
13	2646.34	O-H(Carboxylic acid)
14	2245.14	.C=N(Nitrile)
15	2222.00	C=C(Nitrile)
16	2167.99	C
17	1959.68	C-H(Phenyl substitution overtones)
18	1897.95	C-H(Phenyl substitution overtones)
19	1851.66	C-H(Phenyl substitution overtones)
20	1666.50	C=C(Alkenes) C=O(Amide)
21	1527.62	N-H(Amine)(Scissoring,bending)
22	1442.75	C-H(Alkanes) CH_2(Bending)
23	1226.73	C-O(Aldehyde,ketone.carboxylic acid,ester) C-N(Amine)
24	1157.29	C-O(Aldehyde,ketone,carboxylic acid,ester)
25	1041.56	C-N(Amine) C-O(Aldehyde,ketone.carboxylic acid,ester)
26	956.69	C-H(Alkenes)
27	840.96	C-H(Alkenes)(Arenes,C-H bending and ring puckering)
28	779.24	CH_2(Bending) C-H(Alkenes)(Arenes C-H Bending and ring puckering)
29	748.38	C-H(Alkenes)(Arenes C-H Bending and ring puckering)

Water uptake

Membrane-1

%Water content=wet sample weight-Dry sample weight/wet sample weight X100

=[0.8624-0.3323/1.33] x100/(3.14x4x4.2x4.2x4.2)

=0.04279.

Membrane-2

W_1 =0.8634; W_2 =0.4053; dwater=1.33; v =πr²

= [0.5301/1.33] ×100/3.14×4.2×4.2×4.2

= 0.0427

Membrane-3

W_1 =2.6944; W_2 =2.0424; dwater=1.33; v =πr²

=[0.6520/1.33] ×100/3.14×3.5×3.5×3.5

= 0.0909

Water compaction

Membrane-1

J_W=Q/AΔV

19/ (3.14x4.2x4.2x (3/60))

=6.8606

Membrane-2

Q=19 ; A=πr² ; π=3.14 ; r=3.5;

J_W = 19/3.14×3.5×3.5×0.033

= 14.8344

Membrane-3

Q=19 ; A=πr² ; π=3.14 ; r=3.5;

J_W = 19/3.14×3.5×3.5×0.0500

= 9.8793

Membrane thickness:

The thickness of the cast membrane was measured using

Volume : 5 | Issue : 6 | June 2016 • ISSN No 2277 - 8179 | IF : 3.508 | IC Value : 69.48

WIRA Digital thickness tester (WIRA Instrument, UK). The thickness of the membrane-1,2,3 was found to be 0.53mm,0.55mm and 0.76mm.

TGA Analysis:
The weight loss of the membrane was analysed by thermo gravimetric analysis. It was measured from a temperature of 30 up to 210 and it is indicated in fig-5,6&7.

Figure- 5 Thermo gravimetric analysis of membrane-1

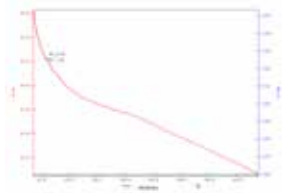
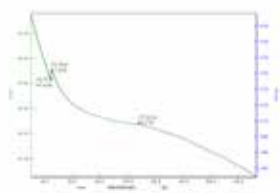


Figure - 6 TGA images of Membrane-2



The membrane was found to be stable till a temperature of 40and then it is found to be steadily decreasing. At 40the membrane was 97.12%

The membrane was found to be stable till a temperature of 43.7and then it is found to be steadily decreasing. At 43.7the membrane was 97.22%.

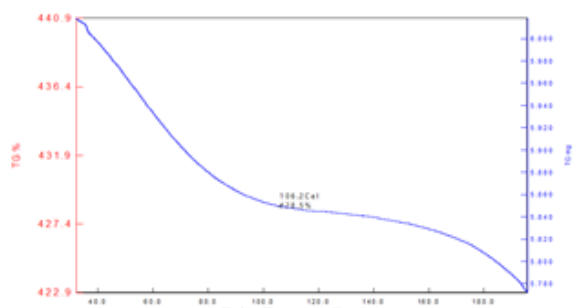


Figure 7 TGA images of Membrane-3

The membrane was found to be stable till a temperature of 40and then it is found to be steadily decreasing. At 40the membrane was 97.12%.

X-Ray diffraction:
X-ray diffraction pattern of the membrane-1 was analysed, and no peaks were found. The membrane -2 showed a sharp peak at 65.6872nm(fig-8) and no peak was observed for membrane-3.

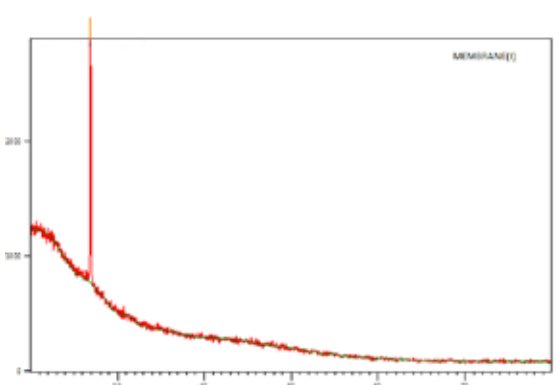


Figure 8 X-Ray diffraction images of membrane-2

5.7 SEM:
The SEM analysis of the membrane -1,2,3 are shown in fig-9,10 &11.

Figure- 9 Scanning Electron Microscopic image of the membrane-1

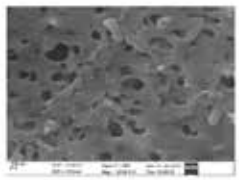


Figure- 10 SEM image of the membrane-2

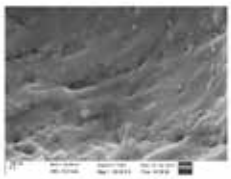


Figure 11 SEM images of the membrane-3

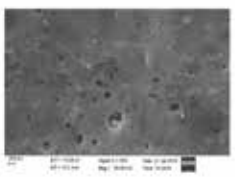


Table 4
Physico-chemical parameters of Sample water and filtered water using membrane-1,2 & 3

S.NO	PARAMETER	SAMPLE WATER	MEMBRANE-1	MEMBRANE-2	MEMBRANE-3
1	PH	7.58	8.20	7.96	7.58
2	Electrical conductivity(ds/m)	1.21	1.19	1.19	1.19
3	Calcium(mg/L)	52.80	41.6	43.2	38.4
4	Magnesium(mg/L)	59.41	48.07	50.78	36.2
5	Sodium(mg/L)	132.25	53.59	75.21	53.59
6	Potassium(mg/L)	14.04	9.36	14.04	9.36
7	Carbonate(mg/L)	1.60	0.08	1.60	1.60
8	Bicarbonate(mg/L)	4.40	3.20	3.20	3.20
9	Chloride(mg/L)	77.8	9.52	9.52	8.16
10	BOD	3.8	4.2	4.6	3.8
11	COD	12.1	10	15	12.1
12	Dissolved oxygen	7.9	5.6	6	5.2
13	Bacteria	11×10^5	9×10^5	9×10^5	4.5×10^5
14	Fungi	9×10^3	5.5×10^3	5.5×10^3	1.5×10^3

Table 5
Hardness measurement for sample water and filtered water using membrane-1,2&3

S.NO	PARAMETER	SAMPLE WATER	MEMBRANE-1	MEMBRANE-2	MEMBRANE-3
1	Calcium carbonate	1.60	0.80	1.60	1.60
2	Magnesium chloride	2.73	0.59	0.24	-
3	Magnesium bicarbonate	3.12	2.16	2.92	2.16
4	calcium bicarbonate	1.28	1.04	0.28	-
5	Sodium chloride	1.81	0.09	0.09	1.90

pH:
pH is an important indicator which indicates acidic and alkaline nature of water. pH should be in the level of 6.6 to 8.4(World Health Organisation).The pH of the sample water was found to be 7.58. The sample water was filtered using membrane-1, membrane-2 and membrane-3 and tested for pH. (table-4)

The obtained values were compared with the standard value of World Health Organisation and it was found that the values were in good agreement.

Electrical conductivity (EC):
Electrical conductivity (EC) is used to determine the cell

constant value. The electrical conductivity of the sample water has the value 1.21(ds/m). The sample water after filtration through membrane-1,2,3 the electrical conductivity was measured and the value obtained was 1.19(ds/m) for membrane-1.1.19(ds/m) for membrane-2 and 1.19(ds/m) for membrane-3(table-4).

Calcium Hardness:
In drinking water, Calcium hardness should be in the level of 75mg/L (World Health Organisation). The calcium hardness of sample water was found to be 52.80mg/L. The sample water was filtered using Membrane-1,2,3 and tested for Calcium Hardness.(table-4)

The obtained values were compared with the standard value of World Health Organisation and it was found that the values were in good agreement.

Magnesium Hardness:
In drinking-water, Magnesium hardness should be in the level of 150mg/L (world health organization 2003). The Magnesium hardness of sample water was found to be 59.41mg/L. The sample water was filtered using Membrane-1,2,3 and tested for Magnesium hardness. It was observed that the Magnesium hardness of filtered water was found to be 48.07mg/L for membrane-1 50.78 mg/L for membrane-2 and 7.58mg/L for membrane-3.(table-4)

The obtained values were compared with the standard value of World Health Organisation and it was found that the values were in good agreement.

Potassium hardness:
In drinking-water, potassium hardness should be in the level of 82mg/L (world health organization 2003).The Potassium hardness of sample water was found to be 14.04mg/L. The sample water was filtered using Membrane and tested for potassium hardness. The sample water was filtered using Membrane-1,2,3 and tested for potassium hardness. (table-4)

The obtained values were compared with the standard value of World Health Organisation and it was found that the values were in good agreement.

Sodium:
In drinking-water, sodium hardness should be in the level of 200mg/L (world health organization 2003).The sodium hardness of sample water was found to be 132.25mg/L. The sample water was filtered using membrane and tested for sodium hardness. The sample water was filtered using Membrane-1,2,3 and tested for sodium hardness. (table-4)

The obtained values were compared with the standard value of World Health Organisation and it was found that the values were in good agreement.

Carbonate:
The carbonate hardness should be in the level of 500 mg/L (World Health Organisation 2008). The value of carbonate for the sample water is found to be 1.06 mg/L. The sample water was filtered using Membrane-1,2,3 and tested for carbonate hardness. (table-4)

The obtained values were compared with the standard value of World Health Organisation and it was found that the values were in good agreement.

Bicarbonate:
The bicarbonate hardness should be in the level of 100 mg/L (World Health Organisation 2008). The value obtained for the bicarbonate in the sample water is 4.40mg/L. The sample water was filtered using Membrane-1,2,3 and tested for bicarbonate hardness. It was observed that the bicarbonate hardness of filtered water was found to be 3.20mg/L for membrane-1 3.20 mg/L for membrane-2 and 3.20mg/L for membrane-3. (table-4)

The obtained values were compared with the standard value of World Health Organisation and it was found that the values were in good agreement.

Dissolved oxygen:
In drinking-water, Dissolved oxygen should be in the level of 30mg/L (World health organization 2003).The Dissolved oxygen of sample water was found to be 7.9mg/L. The sample water was filtered using Membrane and tested for Dissolved oxygen. The sample water was filtered using Membrane-1,2,3 and tested for dissolved oxygen. (table-4)

The obtained values were compared with the standard value of world health organisation and it was found that the values were in good agreement.

Biological oxygen demand:
Biological oxygen demand is the measure of degradation of organic matter present in water. The Biological oxygen demand refers to the oxygen used by the micro-organisms in the aerobic oxidation of organic matter. The Biological oxygen demand of sample water was found to be 3.8 mg/L. The sample water was filtered using Membrane-1,2,3 and tested for biological oxygen demand. It was observed that the biological oxygen demand of filtered water was found to be 4.2mg/L for membrane-1 4.6 mg/L for membrane-2 and 3.8mg/L for membrane-3. (table-4)

The obtained values were compared with the standard value of world health organisation and it was found that the values were in good agreement.

Chemical oxygen demand:
Chemical Oxygen Demand is another measure of organic material contamination in water specified in mg/L. Chemical Oxygen Demand is the amount of dissolved oxygen required to cause chemical oxidation of the organic material in water. The Chemical Oxygen Demand of sample water was found to be 12.1 mg/L. The sample water was filtered using Membrane-1,2,3 and tested for chemical oxygen demand. (table-4)

The obtained values were compared with the standard value of world health organisation and it was found that the values were in good agreement.

Chloride:
Chloride is an important parameter in accessing the water quality. The values of chlorides in normal drinking water are range 250 mg/L (world Health organization 2003). The sample water has the chloride value of 77.8mg/L. The sample water was filtered using Membrane-1,2,3 and tested for Magnesium hardness. It was observed that the Magnesium hardness of filtered water was found to be 9.52mg/L for membrane-1 9.52 mg/L for membrane-2 and 8.16mg/L for membrane-3. (table-4)

The obtained values were compared with the standard value of world health organisation and it was found that the values were in good agreement.

Bacteria:
The bacterial growth was observed in the sample water and

Volume : 5 | Issue : 6 | June 2016 • ISSN No 2277 - 8179 | IF : 3.508 | IC Value : 69.48

was having the value 11x105mg/L. The sample water was filtered with the membrane-1,2,3 and the bacterial growth was observed for the filtered water and the value obtained was 9 x105mg/L. (table-4)

Fungi:
The fungal growth was observed in the sample water and was having the value 9x103mg/L. The sample water was filtered with the membrane and the fungal growth was observed for the filtered water and the value obtained was 5.5 x 103mg/L. (table-4)

SUMMERY AND CONCLUSION
The aim of this study is to prepare the Green membrane using low toxicity solvent.

The physico-chemical parameter values of the filtered water using the prepared membrane were compared with the values described by the world health organisation and the values mostly is in good agreement.

The membrane preparation is an eco-friendly method and it is easy to handle and it is a low cost method also.

REFERENCES:

1. Amjad,Z., Ed. Reverse Osmosis: Membrane Technology, Water Chemistry,and Industrial Application; Van Nostrand Reinhold: New York,1993.
2. Y.Zhao,L.Song,A.L.Ong,Fouling behaviour and foulant characteristics of reverse osmosis for treated secondary effluent reclamation, Journal of membrane science 349(2010) 65-74.
3. J. Yang, S. Lee, E.Lee, S. Hong, Effect of solution chemistry on the surface properties of reverse osmosis membranes under seawater conditions, Desalination 247(2009) 148-161.
4. M. Kumar,S.S Adham, W.R. Pearce, Investigation of seawater reverse osmosis fouling and its relationship to pretreatment type, Environ. Sci. Techhnol.40 (2006) 2037-2044.
5. Yang,G. and Zhang, L.N.,J. Membr. Sci., 1998,139:47
6. Zhang,L.N., Guo,J., Zhou, J.P. and Du, Y.M.,J.Appl.polym. sci., 2000, 77:610
7. Gao,Y.H and Ye,L.B., "The basic of membrane separation Technique"(in chinese), science press, Beijing, 989, p.150
8. Hao J.H. and Wang S.H., Acta Polymerica sinica (in chinese), 1997,(5):559
9. Grimshaw, R.G, (1993) "Soil and Moisture Conservation in Central America", Vetiver Grass Technology, Observations from Visits to Panama, Costa Rica, Nicaragua, El Salvador, Honduras, and Guatemala.
10. Juang, R.S.; Lin, L.C(2000) Rates of metal electodeposition from aqueous solutions in the presence of chelating agents. Sep.sci. Technol., 35:1087
11. Caflizares,P.; prez.;Camarillo,R.(2002) Recovery of heavy metals by means of ultrafiltration with water soluble polymers: calculation of design parameters. Desalination, 144:279.