

# Fabrication of Polyvinyl Alcohol/Cellulose Acetate (PVA/CA/PEG) Antibacterial Membrane for Potential Water Purification Application

Hassanien AM<sup>1\*</sup>, El-Hashash MA<sup>1</sup>, Mekewi MA<sup>1</sup>, Guirguis DB<sup>1</sup> and Ramadan AM<sup>2</sup>

<sup>1</sup>Department of Chemistry, Faculty of Science, Ain-Shams University, Cairo, Egypt

<sup>2</sup>Department of Chemistry, Faculty of Science, Helwan University, Cairo, Egypt

## Abstract

In the first part of the present research work, the synthesis and characterization of a multilayer PVA/CA/PEG membrane was attempted. Where membrane performance and applicability was investigated for reverse osmosis (RO) desalination of saline water. For this purposes, various synthetic membranes were prepared and characterized for the desalination process. Reverse osmosis parameters of different multilayer composite membranes were evaluated compared to a reference membrane of a desalination station in Egypt. Values of both salt rejection and water flux were assessed as a measure of membrane efficiency. In the present work, selected samples of CA/PEG and PVA/CA/PEG were engaged as membranes for the reverse osmosis process of different feed concentrations of groundwater, brackish, highly saline and also extremely saline water (sea water). Feed and permeate concentrations were determined by conductivity measurements. In addition, to suitable application of the prepared synthetic membranes, the antimicrobial sustainability was also evaluated where prospective function against gram +ve and gram -ve was depicted.

**Keywords:** Reverse osmosis; Polyvinyl alcohol; Polyethylene glycol; Cellulose acetate; Salt rejection; Water flux; Feed concentration; Antimicrobial activity

## Introduction

Reverse osmosis is a membrane separation process in which the water from a pressurized saline solution is separated from the solutes (the dissolved materials) blowing through a semi permeable membrane [1]. Reverse osmosis process has been commercially used since the early 1970s because no heating or phase change is necessary for this separation technique and the energy requirements are low in comparison to the other processes of desalination. The major energy required for desalination is for pressurizing the feed water. Basically, the saline feed water is pumped into a closed vessel where it is pressurized against the membrane. A portion of the water passes through the membrane and the remaining feed water poses an increased salt content. i.e., at the same time, a portion of this feed water is discharged without passing through the membrane and without this controlled discharge, it would continue its salt concentration, creating problems such as precipitation of supersaturated salts and increased osmotic pressure across the membrane. Basic studies relating to membranes and the reverse osmosis process continue to provide the foundation for developing the technology of reverse osmosis [2]. Advantages of this membrane are desalting removal of bacteria and viruses from feed water. Also the energy consumption is low when compared to other desalination process, it is also recognized that the membrane should be chemically inert, mechanically strong, and creep resistant. The membrane should be also capable of being fabricated into configuration of high surface to volume ratio [3]. To render the surface of ultra-filtration membranes biocidal, cellulose membranes were modified with PVA, a naturally occurring polycationic biocide. Through the use of membranes with different pore sizes, the alteration of the morphological structure of composite layers was achieved. The importance of such structural differences in the antimicrobial activity of the prepared membranes against gram-negative *Escherichia coli* was studied. The antimicrobial efficiency improved with the use of composition with higher molecular weights and membranes with smaller pore sizes. This suggested that the surface location of the grafted membrane chains was more preferential

for a higher antimicrobial activity of the surface. Membranes modified with PEG showed higher antimicrobial efficiency against gram-positive (*Staphylococcus sp.*) and gram-negative (*Pseudomonas sp.*) In recent years, self-sterilizing surfaces have attracted growing interest. Products with an added antimicrobial treatment are finding excellent acceptance by the medical community. They include surgical drapes, instrument wraps, and surgical packs that reduce the risk of postoperative infection [4] and tooth fillings [5]. Microbiological evaluations have been carried out on a variety of textile materials [6] and food packaging [7] treated with antimicrobial agents. They have been treated against a broad spectrum of microorganisms, including odor-causing bacteria as well as bacteria and fungi, which cause rot and mildew. Most such materials are based on compositions that release biocidal molecules or ions. However, the application of polymer biocides has opened new frontiers in the development of nonleaching antibacterial surfaces [8,9]. Recently attempts have been made to render membrane surfaces antimicrobial by graft copolymerization and interfacial. Polycondensation of amine-containing polymers, which are potentially antimicrobial agents [10,11]. In this study, composite membrane, the antimicrobial properties of which are well documented [12,13] and was tethered to the surfaces of cellulose membranes to provide them biocidal activity and thereby lower the membrane biofouling potential. The membrane bactericidal activity was tested against gram (-ve) and gram (+ve). The influence of the modification conditions, molecular weight of the composite membrane, and morphological structure

**\*Corresponding author:** Hassanien AM, Faculty of Science, Ain-Shams University, Cairo, Egypt, Tel: 02-01221891549; Fax: 02-44714295; E-mail: [amera\\_muhammad@hotmail.com](mailto:amera_muhammad@hotmail.com)

**Received** December 07, 2012; **Accepted** December 20, 2012; **Published** December 24, 2012

**Citation:** Hassanien AM, El-Hashash MA, Mekewi MA, Guirguis DB, Ramadan AM (2013) Fabrication of Polyvinyl Alcohol/Cellulose Acetate (PVA/CA/PEG) Antibacterial Membrane for Potential Water Purification Application. *Hydrol Current Res* 4: 146. doi:10.4172/2157-7587.1000146

**Copyright:** © 2013 Hassanien AM, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

of the membranes on the antimicrobial properties of the prepared membranes was studied. Adv. Mat. Lett. 2011, 2(1), 17-25; 2) Adv. Mat. Lett. 2010, 1(2), 123-128; 3) Adv. Mat. Lett. 2010, 1(1), 59-66; 4) Adv. Mat. Lett. 2012, 3(2), 136-142; 5) Adv. Mat. Lett. 2012, 3(2), 259-264; 6) Polysaccharides: development, properties and applications, Nova Science Publishers, Inc., New York, USA, ISBN: 978-1-60876-544-7, 2010; 7) Recent Developments in Bio-Nanocomposites for Biomedical Applications, Nova Science Publishers, Inc., New York, USA, ISBN: 978-1-61761-008-0, 2010.

## Experiment

Some of the previously selected membranes were used; the selected membranes are shown in Table 1. The selection criteria were good water flux with acceptable salt rejection [1]. Which PVA is: polyvinyl alcohol, china manufacturing, with 99.9% purity. CA is: cellulose acetate, china manufacturing, with 96% purity. And PEG is: polyethylene glycol, USA manufacturing, with 95% purity. Some of experiments had taken place in Ain Shams University, Cairo, Egypt and others in National Center for Radiation Research and Technology, Atomic energy Authority, Egypt.

## Membrane characterization and functional features

Structural and functional studies of the PVA/CA grafted RO membranes were conducted and evaluated through the following analytical, functional and structural characterization techniques.

**Mechanical Properties:** The dumbbell shape samples were cut with dimension 50 mm long 25 mm neck and 4mm wide. Mechanical measurements were carried out through measuring both tensile strength and elongation percent by using an Instron (Model-1195, England) which is installed at National Center for Radiation Research and Technology, Atomic energy Authority, Egypt.

**FT-IR spectroscopic analysis:** Analysis by Infrared spectroscopy was carried out using Genesis Unicam FT-IR spectrophotometer. The dimensions of the window, to which the film was fixed, were 1.5X3 cm. FT-IR studies were conducted at the Central Laboratory of Ain-Shams University- Abbassia, Cairo.

**Surface and topographical studies:** The surface morphologies of the hydro gels as well as the surface of the membranes were investigated by SEM images using a JSM-5800 instrument, JEOL, (Japan). The polymer films were gold coated before the study. Photographs were taken X100 magnification. Tapping mode on a commercial AFM (Pico scan, Molecular Imaging, Tempe, AZ, USA) was also employed to aid with topography and phase images of the polymer membrane surfaces. AFM tapping mode technique allows high resolution topographic mapping of sample surfaces that are easily damaged, such as the polymer membrane films. After image acquisition, the roughness of the membrane surface was determined by a built-in image processing toolbox in the AFM software. SEM and AFM images were performed at National Center for Radiation Research and Technology, Atomic energy Authority, Egypt.

**Thermal stability profile (TGA):** Thermal stability and the solid state dehydration changes of the membrane samples were carried out using a Shimadzu DT-60H thermal analyzer, Shimadzu, Kyoto, Japan, measured from ambient temperature up to 500°C at a heating rate of 15 deg /minute, available at National Center for Radiation Research and Technology, Atomic energy Authority, Egypt.

## Results and Discussion

### Calibration of RO properties of different synthetic composite membranes

Reverse osmosis properties of different types of synthetic composite membranes were calibrated against Film Tech SW30 membrane that is already in use in the desalination station in Egypt. This calibration was carried out by comparing the values of both salt rejection and water flux as shown in Table 2, using reverse osmosis laboratory unit at the operation conditions of NaCl solution (EC 15000  $\mu$  mhos), 30 bar applied pressure, flow rate 3 lL/min for 6 hours as the operation time. The best membrane result (PVA+CA/PEG), that gives salt rejection (64%) and gives water flux (84.5%).

**Membrane preparation:** Poly (vinyl alcohol) casting solution was prepared by dissolving 5wt. % (PVA) in water at 90°C with constant stirring until homogenous solution was obtained. After that add 0.001 wt% of the crosslinking agent is malice acid. The resultant polymer solution was cast on a glass plate and the plate was subsequently placed in an oven at 50°C overnight and washed with distilled water before used. Also preparation of CA by the same technique then casting preparation. The solution was casted on a solid flat and horizontal surface of glass plate. Prior to the casting process, the glass plate was cleaned by vigorous scrubbing of the surface with a quiet liquid laboratory detergent, large volume of tap water followed by several rinse of distilled water. The membrane was allowed to dry and the solvent was slowly evaporated in an oven at temperature 50°C for 18 hr. After drying, the membrane is floated off and the thickness of the film was determined by the thickness gauge.

### Applications of CA/PEG reverse osmosis membrane in desalination of saline water samples

The selected CA/PEG reverse osmosis membranes were of composition 1:1 CA/PEG copolymer ratio at 100  $\mu$  membrane thickness. The selected membrane possesses good mechanical properties (tensile strength=63.5 M Pa and elongation=49.88%) and suitable  $R_s$  and  $J_{H_2O}$  for different feed concentrations [1]. Three water samples were used. Two ground water samples (brackish, highly saline) and extremely saline water (sea water) were used. The waste (brine) water was recycled to maintain a constant concentration in the feed tank by adding distilled water and is briefed as follows.

**Desalination of highly saline water (sea water):** The feed of sea water (TDS=13986.07 ppm), of slightly alkaline pH=7.4 is pumped into a closed vessel in the reverse osmosis unit, where it is pressurized at 40 bar with a flow rate of 3 l/minute against the RO membrane. This pressure value is needed to enable the fresh water to pass through the

Membrane	Added layer	Synthesis Technique	Ratio %	Thickness, $\mu$
PVA/CA	PEG1	Chemical Technique	5%	70
PVA/CA	PEG2	Chemical Technique	10%	100
PVA/CA	PEG3	Chemical Technique	15%	180
PVA/CA	PEG4	Chemical Technique	20%	220

Table 1: Multilayer membranes description.

Membrane type	Reverse Osmosis properties	
	$R_s$ (%)	$J_{H_2O} \times 10^{-5}$ (gm/cm <sup>2</sup> .sec)
Film Tech SW30-8040-A (reference)	64	50
CA & PEG	61	2.47
PVA & CA	49.42	6.77
PVA+CA & PEG	64	84.5

Table 2: Comparison of reverse osmosis properties of different synthetic membranes with the commercial type membrane (Film Tech SW30).

membrane leaving an amount of rejected salts; some amounts of salts pass through the membrane and remained in the product water. The results show that the total mineralization (water salinity) as well as the ionic composition of the groundwater decrease gradually as a function of desalination operation time. By using the selected membrane, the values of electric conductivity and total dissolved solids of post treatment water became 12850  $\mu$  mhos, 7036 mg/l, (10750  $\mu$  mhos, 5857 mg/l) and (9050  $\mu$  mhos, 5059 mg/l) at operation times of 8, 16 and 24 hr., respectively, results are shown in Table 3.

**Desalination of brackish water:** The feed of brackish water (TDS=3333 ppm) of slightly alkaline pH (7.8) is pumped into a closed vessel in the reverse osmosis unit, where it is pressurized by 30 bar with a flow rate of 5.1/min against the RO membrane. This pressure is needed to enable the fresh water to pass through the membrane leaving an amount of salts rejected; some amounts of salts pass through the membrane and remained in the produced water. The results show that the total mineralization (water salinity) as well as the ionic composition of the saline water decrease gradually as a function of desalination operation time. By using the selected membrane, the values of electric conductivity and total dissolved solids of post treatment water became The EC and TDS of post treatment water became (2800  $\mu$  mhos, 1620 mg/l), (2200  $\mu$  mhos, 1301 mg/l) and (1680  $\mu$  mhos, 933 mg/l) for operation times of 5, 8, 16 and 24 hours, respectively, as shown in Table 4.

**Desalination of sea water (extremely saline water):** The feed concentration of sea water (TDS= 42847 mg/l) and alkaline pH=7.9 is pumped into a closed vessel in the RO unit, where it is pressurized at 50 bar against the PVA/CA/PEG composite membrane. The results show that the total mineralization (water salinity) and the ionic concentration of the sea water decreases gradually as a function of operation time increase. By using the selected membrane, the values of electrical conductivity and total dissolved solids of post-treated water became 39200  $\mu$  mhos, 24690 mg/l; 34350  $\mu$  mhos, 21946 mg/l; and 27500  $\mu$  mhos, 16722 mg/l at operation times of 8, 16 and 24 hours, respectively and a shown in Table 5.

After treatment of brackish groundwater sample, the obtained produced water has a low value of TDS (933 mg/l), which is accepted by International standards because this salinity is suitable for human consumption of drinking water, Tables 6-9.

A large operating pressure is due to the effect of Donnan exclusion which reduces with increasing feed electrolyte concentrations. In case of a rejection is obtained. This type of retention sequence was observed by several other authors as well [14-16].

### Evaluation of membranes antimicrobial activity

Gram-negative *Pseudomonas* sp. and Gram-positive *Staphylococcus* sp. bacteria strains were received from the Antibiotic standard used: Amikan (AK) of Microorganisms [17]. The bacteria were grown and maintained in Nutrient Agar disk diffusion No. 1 (Fluka). Microbial suspensions were prepared in a sterilized physiological solution. Fifty-microliter suspensions containing  $(4-5) \times 10^5$  cells/mL were diluted in 50 mL of a physiological solution and then were filtered through the membrane at an operating pressure of 200 kPa. After filtration, the membranes Scheme 1 Chemical transformations of cellulose modification were incubated in Nutrient Agar medium for 24 h at 30°C. The bactericidal activity was determined in terms of the growth inhibition, which was calculated with the Following equation: Growth inhibition  $\frac{1}{4} \frac{N1-N2}{N1} \times 100\%$  where N1 and N2 are the numbers of viable colonies on control and modified membranes, respectively. An unmodified membrane was used as a control and comparison.

### Different Types of microorganisms found in water causes diseases?

There are various bacteria and protozoa that can cause disease when they are present in surface water. Bacteria are not only known to cause disease when they enter a human body through food, surface water may also be an important source of bacterial infection. In this table you can see various bacteria that can be found in surface water, and the diseases they cause when swallowed in large amounts, along with the symptoms.

Bacteria	Disease/infection	Symptoms
<i>Aeromonas</i>	Enteritis	Very thin, blood and mucus-containing diarrhoea
<i>Campylobacter jejuni</i>	Campylobacteriose	Flue, diarrhoea, head and stomachaches, fever, cramps and nausea
<i>Escherichia coli</i>	Urinary tract infections, neonatal meningitis, intestinal disease	Watery diarrhea, headaches, fever, homiletic uremia, kidney damage
<i>Plesiomonas shigelloides</i>	Plesiomonas-infection	Nausea, stomachaches and watery diarrhea, sometimes fevers, headaches and vomiting
<i>Salmonella</i>	Typhoid fever	Fevers
	Salmonellosis	Sickness, intestinal cramps, vomiting, diarrhea and sometimes light fevers
<i>Streptococcus</i>	(Gastro) intestinal disease	Stomachaches, diarrhea and fevers, sometimes vomiting
<i>Vibrio El Tor</i> (freshwater)	(Light form of) Cholera	Heavy diarrhea

Protozoa can accumulate in certain body parts, after they have penetrated a human body. The accumulations are called cysts.

Because of their parasitic nature, protozoa can cause various diseases. In this table you can see various protozoa that can be found in surface water, and the diseases they cause when swallowed in large amounts, along with the symptoms.

Microorganism	Disease	Symptoms
<i>Amoeba</i>	Amoebic dysentery	Severe diarrhea, headache, abdominal pain, chills, fever; if not treated can cause liver abscess, bowel perforation and death
<i>Cryptosporidium parvum</i>	Cryptosporidiosis	Feeling of sickness, watery diarrhea, vomiting, lack of appetite
<i>Giardia</i>	Giardiasis	Diarrhea, abdominal cramps, flatulence, belching, fatigue
<i>Toxoplasma gondii</i>	Toxoplasmosis	Flu, swelling of lymph glands With pregnant women subtle abortion and brain infections

### Antibacterial activity of the composite membranes modified with PEG

Gram+ve bacteria and Gram-ve bacteria give a positive result with the membrane which gives an inhibition zone that indicates that the composite membrane kills these bacteria (Figure 1).

### Conclusion

The PVA/CA/PEG composite multilayer membrane is acceptable for practical uses in desalination of brackish, highly saline and sea (extremely saline water) water, where the salt rejection (%) was 70, 63 and 59, respectively. In other words, the water salinity of brackish (3333 mg/l), highly saline groundwater (13986 mg/l) and sea water (42847 mg/l) became 933, 5059 and 16722 mg/l after desalination

Operation time	TDS (mg/l)	unit	Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	Total cations	CO <sub>3</sub> <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	Cl <sup>-</sup>	Total anions	Hypothetical salts (%)				
													Na Cl	Mg Cl <sub>2</sub>	Ca Cl <sub>2</sub>	Ca SO <sub>4</sub>	Ca (HCO <sub>3</sub> ) <sub>2</sub>
Pre-treatment (Row water)	13986.07	mg/l	1009	589.3	3261	60	242.19	0	244	1970	6975	241.69	59	20	3	16	2
		me/l	50.34	48.46	141.85	1.53		0	3.99	41.02	196.70						
		%	20.79	20.01	58.57	0.63		0	1.65	16.97	81.38						
Produced water after 8 hr.	7036.78	mg/l	582	259.3	1630.5	20	121.80	0	134.2	950	3534	121.43	58	18	6	16	2
		me/l	29.04	21.32	70.93	0.51		0	2.19	19.78	99.66						
		%	23.84	17.51	58.23	0.42		0	1.64	16.29	82.07						
Produced water after 16 hr.	5856.81	mg/l	388	188.6	1535.5	17	102.10	0	122	520	3162	101.49	66	15	6	11	2
		me/l	19.36	15.51	66.79	0.43		0	1.99	10.83	89.17						
		%	18.96	15.19	65.42	0.43		0	1.47	10.67	87.86						
Produced water after 24 hr.	5059.11	mg/l	213.4	153.2	1442	17	86.41	0	91.5	320	2883	88.96	73	15	3	7	2
		me/l	10.65	12.60	62.73	0.43		0	1.49	6.66	81.30						
		%	12.32	14.58	72.60	0.50		0	1.12	7.49	91.39						

Table 3: Chemical analysis data of raw water and post treatment of extremely samples using CA & PEG reverse Osmosis membrane.

Operation time	TDS (mg/l)	unit	Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	Total ations	CO <sub>3</sub> <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	Cl <sup>-</sup>	Total anions	Hypothetical salts (%)				
													Na Cl	Mg Cl <sub>2</sub>	Mg SO <sub>4</sub>	Ca SO <sub>4</sub>	Ca (HCO <sub>3</sub> ) <sub>2</sub>
Pre-treatment (Row water)	3333	mg/l	334.8	180.8	614	5.09	58.41	0	244	900	1176	55.89	46	18	7	22	7
		me/l	16.71	14.87	26.70	0.13		0	3.989	18.73	33.16						
		%	28.6	25.46	45.72	0.22		0	7.14	33.53	59.33						
Produced water after 8 hr.	1620	mg/l	167.4	79.1	316.6	1.82	28.67	0	122	370	624	27.29	48	17	6	22	7
		me/l	8.353	6.505	13.77	0.04		0	1.99	7.7	17.59						
		%	29.13	22.68	48.03	0.16		0	7.42	28.22	64.27						
Produced water after 16 hr.	1301	mg/l	130.2	56.5	252	1.36	22.14	0	106.8	280	528	22.46	50	15	6	21	8
		me/l	6.497	4.65	10.96	0.034		0	1.74	5.82	14.88						
		%	29.33	21	49.51	0.16		0	7.77	25.39	64.84						
Produced water after 24 hr.	933	mg/l	93	33.9	209	1.36	16.53	0	76.25	150	408	15.87	55	14	3	20	8
		me/l	4.641	2.79	9.07	0.034		0	1.24	3.123	11.50						
		%	28.07	16.86	54.86	0.21		0	7.85	18.79	69.21						

Table 4: Chemical analysis data of raw water and post treatment of highly saline water samples using PVA+CA reverse osmosis membrane.

Operation time	TDS (mg/l)	unit	Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	Total cations	CO <sub>3</sub> <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	Cl <sup>-</sup>	Total anions	Hypothetical salts (%)				
													NaCl	MgCl <sub>2</sub>	MgSO <sub>4</sub>	CaSO <sub>4</sub>	Ca(HCO <sub>3</sub> ) <sub>2</sub>
Pre-treatment (Raw water)	42847.12	mg/l	520.8	1672	12902	380	734.48	0	244	4000	23250	742.92	77	11	8	3	1
		me/l	25.99	137.53	561.24	9.72		0	3.99	83.28	655.65						
		%	3.54	18.73	76.41	1.32		0	0.54	11.21	88.20						
Produced water after 8 hours	24689.96	mg/l	334.8	836.2	7500	240	417.86	0	183	2900	12788	423.98	80	5	11	3	1
		me/l	16.71	68.77	326.25	6.14		0	2.99	60.38	360.61						
		%	3.99	16.46	78.08	1.47		0	0.71	14.24	85.05						
Produced water after 16 hours	21946.01	mg/l	297.6	723.2	6714	210	371.75	0	152.5	2300	11625	378.20	80	5	11	3	1
		me/l	14.85	59.47	292.06	5.37		0	2.49	47.89	327.83						
		%	3.99	16.00	78.57	1.44		0	0.66	12.66	86.68						
Produced water after 24 hours	16721.95	mg/l	223.2	542.4	5104	102	280.38	0	122	1680	9009.4	291.04	80	6	10	3	1
		me/l	11.14	44.61	222.02	2.61		0	1.99	34.98	254.06						
		%	3.97	15.91	79.19	0.93		0	0.69	12.02	87.29						

Table 5: Chemical analysis data of pre-treated and post treated sea water sample using PVA+CA&PEG composite membrane after each operating time through desalination process.

time of 24 hr. for one run of such membrane but these values of produced water salinity can be decreased by increasing the number of the used membranes. On the other hand, the water flux decreases with increasing feed concentration during operating time 24 hr, where

water flux was 10.32, 9.26 and 8.18 (gm/cm<sup>2</sup>.s×10<sup>-5</sup>) for brackish, highly saline and sea water, respectively. The lowering of water flux with the increase of operation time is due to the accumulation of the salts in the pores of membrane.

Time (hr)	Rs (%)	Salt passage (%)	$J_w \times 10^{-5}$ ( gm/cm <sup>2</sup> .s)	Salinity of pre-treated Water (Row water) (mg/l)	salts (%) of TDS of feed concentration				
					NaCl	Mg Cl <sub>2</sub>	Mg SO <sub>4</sub>	Ca SO <sub>4</sub>	Ca (HCO <sub>3</sub> ) <sub>2</sub>
0	0	100	0	3333	46	18	7	22	7
				Salinity of post-treated water (mg/l)	Salt rejection (%)				
8	51	49	15.43	1619.9	22.67	9.74	4.08	11.31	3.60
16	61	39	14.20	1301.4	26.47	12.14	4.66	13.80	3.88
24	70	28	10.28	932.8	30.60	14.08	6.16	16.40	4.76

Table 6: Reverse osmosis parameters for the PVA/CA+PEG membrane in desalination of brackish water sample.

Time (hr.)	R (%)	Salt passage (%)	$J_w \times 10^{-5}$ ( gm/cm <sup>2</sup> .s)	Salinity of pre-treated Water (Row water) (mg/l)	salts (%) of TDS of feed concentration				
					NaCl	Mg Cl <sub>2</sub>	Ca Cl <sub>2</sub>	Ca SO <sub>4</sub>	Ca (HCO <sub>3</sub> ) <sub>2</sub>
0	0	100	0	13986	59	20	3	16	2
				Salinity of post-treated water (mg/l)	Salt rejection (%)				
8	49.7	50.31	13.88	7036.78	29.82	10.94	0.22	7.95	0.99
16	58.1	41.88	10.80	5856.81	31.36	13.72	0.49	11.39	1.16
24	63.8	36.17	9.26	5059.11	32.59	14.57	1.91	13.47	1.28

Table 7: Reverse osmosis parameters for the PVA/CA+PEG membrane in desalination of highly saline water sample.

Time (hr.)	R (%)	Salt passage (%)	$J_w \times 10^{-5}$ (gm/cm <sup>2</sup> .s)	Salinity of pre-treated water (Row water) (mg/l)	salts (%) of TDS in feed concentration				
					NaCl	Mg Cl <sub>2</sub>	Mg SO <sub>4</sub>	Ca SO <sub>4</sub>	Ca (HCO <sub>3</sub> ) <sub>2</sub>
0	0	100	0	42847	77	11	8	3	1
				Salinity of post-treated water (mg/l)	Salt rejection (%)				
8	42.4	57.62	12.85	24689.96	30.90	8.12	1.66	1.27	0.42
16	48.8	51.22	11.82	21946.02	36.02	8.44	2.36	1.46	0.49
24	60.9	39.03	8.18	16721.95	44.77	8.65	4.09	1.83	0.61

Table 8: Reverse osmosis parameter for the PVA/CA+PEG in desalination of sea water sample.

Parameter	Raw water (mg/l)	Permeate conc. (TDS mg/l)	Rs %	$J_w \times 10^{-5}$ (gm/cm <sup>2</sup> .s)
Brackish water	3333	933	69.62	10.28
Highly saline water	13986	5059	63.36	9.26
Sea water	42847	16722	59.14	8.18

Table 9: Comparison between salt rejection and water flux of brackish, highly saline groundwater and sea water samples.



The importance of such structural differences for antimicrobial activity of the prepared membranes has been studied with the use of gram-negative and gram+ve. The highest antimicrobial activity of modified membranes is achievable when the degree of membrane modification is close to its maximal value. Antimicrobial efficiency improves with the use of PEG and membranes with smaller pore sizes. It is believed that immobilized biocides must be sufficiently long to traverse and damage the cellular membrane/wall of bacterial cells in contact with the surface. Modification of membranes with smaller pore sizes occurs entirely on the membrane surface when membranes are modified with PEG. This results in the most expanded layer of bound PEG with the highest activity against *Staphylococcus* and *Pseudomonas*. Consequently, the decrease in the antimicrobial efficiency with the increase in the pore size is more pronounced when membranes are modified with lower molecular weight PEG.

### References

1. El-Hashash MA, Mekewi MA, Guirguis DB, Ramadan AM, Hassanien AM (2011) Polyvinyl Alcohol-Cellulose Acetate Composite Reverses Osmosis Membranes: I. Synthesis And Characterization. *Egypt J Appl Sci* 26: 601-661.
2. Gillam WS (1972) Future trends of OSW membrane research. *Reverse Osmosis Membrane research* 493-500.
3. Lonsdale HK, Padall HK (1972) *Reverse osmosis membrane research*. Plenum press, New York (155)
4. Hilal N, Al-Khatib L, Atkin BP, Kochkodan V, Potapchenko N (2003) Photochemical modification of membrane surfaces for (bio)fouling reduction: a nano-scale study using AFM. *Desalination* 158: 65-72.
5. Danese PN (2002) Antibiofilm approaches: prevention of catheter colonization. *Chem Biol* 9: 873-880.
6. Stashak TS, Farstvedt E, Othick A (2004) Update on wound dressings: Indications and best use. *Clin Technol Equine Pract* 3: 148-163.
7. Imazato S, Ebi N, Takahashi Y, Kaneko T, Ebisu S, et al. (2003) Antibacterial activity of bactericide-immobilized filler for resin-based restoratives. *Biomaterials* 24: 3605-3609.
8. Bajaj PJ (2002) *Appl Polym Sci* 83: 631.
9. Appendini P, Hotchkiss JH (2002) Review of antimicrobial food packaging. *Innov Food Sci Emerg Technol* 3: 113-126.
10. Tiller JC, Lee SB, Lewis K, Klibanov AM (2002) Polymer surfaces derivatized with poly(vinyl-*N*-hexylpyridinium) kill airborne and waterborne bacteria. *Biotechnol Bioeng* 79: 465-471.
11. Lea SB, Koepsel RR, Morley SW, Matyjaszewski K, Sun Y, et al. (2004) *Biomacromolecules* 5: 877.
12. Hilal N, Kochkodan V, Al-Khatib L, Levadna T (2004) Surface modified polymeric membranes to reduce (bio)fouling: a microbiological study using *E. coli*. *Desalination* 167: 293-300.
13. Rabea EI, Badawy MET, Stevens CV, Smagghe G, Steurbaut W (2003) *Biomacromolecules* 4: 1457.
14. Bhattacharya A, Misra BN (1974) Grafting: a versatile means to modify polymers: Techniques, factors and applications. *Progress in polymer Science* 29: 767-814.
15. Simpson AE, Kerr CA, Buckley CA (1987) The effect of pH on the nanofiltration of the carbonate system in solution. *Desalination* 64: 305-319.
16. Ikeda K, Nakano T, Ito H, Kubota T, Yamamoto S (1988) New composite charged reverse osmosis membrane. *Desalination* 68: 109-119.
17. Amikan (2012) *J of microbiology* 23: 300-320.