

## Water Desalination Using Cellulosic Nano-filtration Membrane Composed of Nano-scale Polytetrafluoroethylene

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**T**HIS STUDY deals with the preparation and characterization of Nanofiltration cellulose acetate-based membranes and their application in desalination of brackish water. Cellulose acetate nanofiltration (CA-NF) membranes were prepared using phase inversion process. Pore size of the prepared membrane was checked via dope solutions of different polymer concentrations (wt. %) and treatment temperatures from 60-90°C. followed by casting the membrane on Polytetrafluoroethylene sheets (PTFE) and examining the efficiency of the product. Characterization of the prepared membrane was carried out utilizing scanning electron microscopy (SEM). The work was extended to study the hydraulic permeability, water permeation as well as salt rejection percentage. Characterization of the prepared membrane will be carried out utilizing scanning electron microscopy (SEM), the hydraulic permeability, water permeation as well as salt rejection percentage. Results indicated that CA membranes reinforced with (PTFE) gave better efficiency than normal CA membranes.

**Keywords:** Desalination, Nanofiltration, Cellulose derivatives, Phase inversion process, Membrane.

### Introduction

Nanofiltration membrane is considered as one of the pressure forced membrane that performs a preferential disconnection for different ions or fluids. Nanofiltration membrane pores are generally larger than those of reverse osmosis membranes. Therefore, nanofiltration needs less energy to perform such separation. The feasibility of nanofiltration membranes for the application in water and waste water treatment processes is brought about from their higher flux as well as lower operating pressure. [1]

Due to the shortage of clean drinking water worldwide, water desalination via nanofiltration (NF) and reverse osmosis (RO) membranes becomes the most suitable choice for desalinating brackish and sea water. Nevertheless, the enhancement in membranes emphasizes salt rejection and high fluxes using decreased pressures is of great importance. The precursor membrane composition has been manufactured using phase inversion technique from Cellulose Acetate (CA) and described by Durmaz et al. [2] cellulose acetate with low price and chlorine resistance represents the most interesting polymer.

On the other hand, CA is an eco-friendly product obtained from sustainable and biodegradable resources. The elaboration of membrane material having RO performances has been reported [3-6].

During the past decade, an intermediate nanofiltration method, applying extra open pores with decreased pressures, produced a selective retention among divalent to monovalent ions [7-10].

In contrast to other varieties of desalinating water, brackish water desalination is through some distance the most sophisticated and intricate process. It has the least water recovery percentage (30-35%). Operation is restrictive to favorable operation circumstances. Also, it tends to need inclusive pretreatment, specifically if the input is obtained from an exposed seawater source place. This process consumes energy, and for all prementioned elements seawater desalination is the most expensive desalination way. The main reason for expensive cost and technological sophistication is the seawater itself which is distinct through having: (1) increased hardness content, (2) different degrees of turbidity, and (3) high dissolved salts at pH >8.0. These characteristics show three main

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problems in seawater desalination which yield tough restriction and have said outcomes at the overall performance and productivity of seawater desalination plants [11, 12].

At the present time, nanofiltration became the most widespread technique applied in drinking water industries [13] and wastewater treatment plants for the purpose of contaminants removal processes such as pesticides [14], Heavy metals [15], leachate soil [16] and dyestuff residues [17]. As well as for food applications [18] and biotechnological process. Interfacial polymerization (IP) technique is considered one of the most successful techniques used in composite nanofiltration membranes preparation, which have high salt rejection water and permeation flux. There are a huge number of advantages in membrane designing through using the IP process [19].

Cellulose acetate membrane gets to be those initial unreasonable in general execution uneven membrane. It has been comprehensively utilized for microfiltration (MF), reverse osmosis (RO), Furthermore gas segregation. Cellulose acetate membranes have high hydrophilicity which plays an important role in decreasing besmirch, enhanced resistivity to solvent and chlorine. The regenerated CA membrane which altered to be hydrolyzed from CA has appreciably improved thermal stability and solvent-impedance [20].

Commercial CA membranes would whichever even sheet or spiral-wound modules. The hollow fiber arrangement has elicited as a preferable preference due to the hollow fiber membranes have three distinct benefits:

A- Hollow fiber modules have much bigger proportion for membrane area per unit volume (many. thousand), and therefore more productivity per unit volume of membrane; B-Supporting toward oneself which could make regeneration to recover flux and C-Exact resilience within the mode of operation [21].

The aim of the present work is to produce an advanced nano CA membrane using adjacent PTFE and utilizing the new product in desalinating brackish water.

## **Experimental**

### *Materials*

The chemicals used throughout were Cellulose Acetate (CA) was delivered in the nano form (NCA) as a solution from Sigma chemicals,

Poly tetra Flouro ethylene (PTFE) membrane sheets (kindly supplied by El-Asher Co., 10th of Ramadan City-Egypt), Dimethyl formamide, formamide, and paraformaldehyde were delivered from Fluka, acetic acid, acetone, sodium hydroxide and sodium bicarbonate delivered as analytical grade from ADWIC-Egypt.

### *Preparation of Membranes*

The casting solutions were prepared by dissolving the necessary quantity of NCA (1-6g) in acetone: Dimethyl formamide (2:1) mixture and adjusting the liquor ratio 1:20 according to a method mentioned elsewhere. The mixture was stirred until NCA getting the casting solution. The prepared casting solution was casted on PTFE membrane fixed on a glass plate, at ambient temperature and spread with a casting knife to a certain thickness (140  $\mu\text{m}$ ), and then sunk in a bath containing cold water 5°C, followed by exposure to air for 10 min. [19].

### *Tests*

#### *SEM morphology*

The surface morphologies of the functionalized cellulose acetate at various stages were characterized by using a JEOL JSM 840A (Tokyo, Japan), Scanning Electron Microscope (SEM) at an accelerating voltage of 15 KV.

#### *R.O. Tests*

*Contact Angle measurement:* Contact angle was measured using DSA100W-Wafer device – Kruss GmbH- Germany.

*Salt Rejection and Salt Passage:* The salt rejection describes the quantity of salt removed from the reverse osmosis feed water stream as percentage.

$$\text{Salt Rejection} = \frac{(\text{TDS}_{\text{Feed}} - \text{TDS}_{\text{Product}})}{(\text{TDS}_{\text{Feed}})} \times 100$$

$$\text{Salt Passage} = 1 - \text{Salt Rejection}$$

#### *Feeding water Characteristics*

The characteristics of feeding water listed in Table 1, the ratio of cations and anions was not balanced exactly. This may be attributed to incomplete analysis of some of minor ions were not analyzed. Table 1 shows the total hardness of the incoming water (total of  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$

**TABLE 1. Chemical analysis of brackish water sample from a deep well in Belbis-Sharkya Governorate-Egypt.**

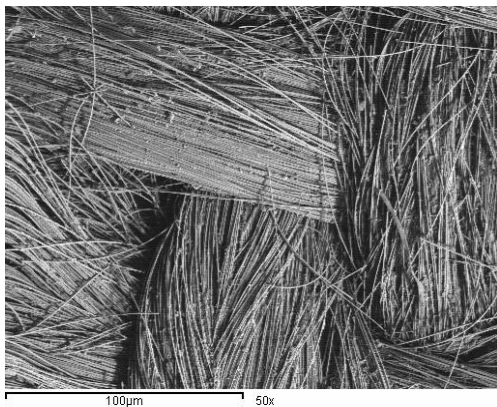
| Anion                         | Concentration | Cation                     | Concentration |
|-------------------------------|---------------|----------------------------|---------------|
| HCO <sub>3</sub> <sup>-</sup> | 820           | K <sup>+</sup>             | 96            |
| Cl <sup>-</sup>               | 520           | Na <sup>+</sup>            | 430           |
| NO <sub>3</sub> <sup>-</sup>  | 170           | Ca <sup>2+</sup>           | 210           |
| SO <sub>4</sub> <sup>2-</sup> | 320           | Mg <sup>2+</sup>           | 130           |
| Total Anion concentration     | 1830          | Total Cation concentration | 866           |

ions) was 340 ppm. Moreover, the sum of the concentration of sodium and chloride ions was about 950 ppm due to possible the increased use of chemical fertilizers that raises the nitrate ions concentration (170 ppm) according to the primary activity of the area of this study.

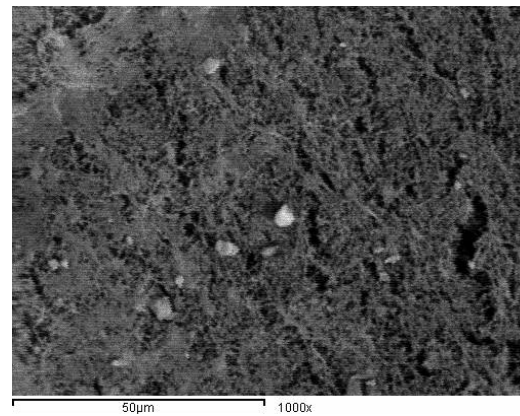
#### *NCA membranes Characterization*

The most effective factors governing the final structure of the asymmetric membranes are the concentration of polymer of the dope solution and

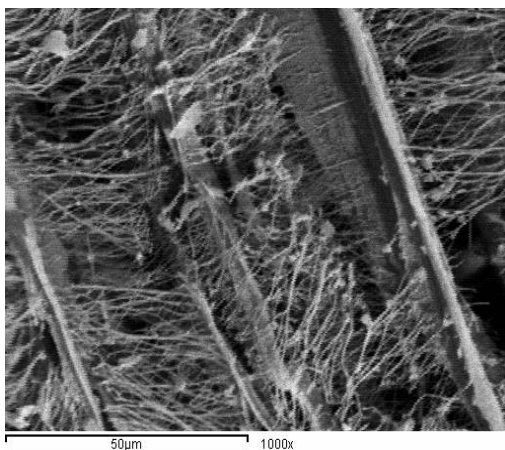
the annealing temperature of the film. It is obvious that by increasing the concentration of polymer, the more compactness in the top layer and the decreased pore size distribution [20]. Meanwhile, by the higher the annealing degree, the higher is the ratio of crystalline domains in the structure of the polymer will occur which produces denser skin layer [21]. These parameters allow membrane designing via working at the pore size distribution and on the thickness of the dense skin layer. Asymmetrical NCA membranes were prepared via



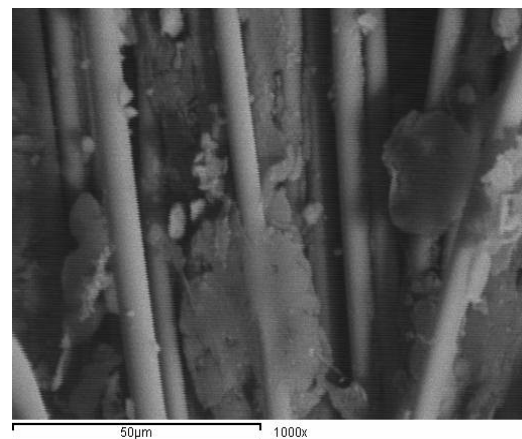
**Fig. 1.** Fiber glass woven fabric (PTFE).



**Fig. 2.** A scanning electron microscope photograph for the PTFE-NCA membrane.



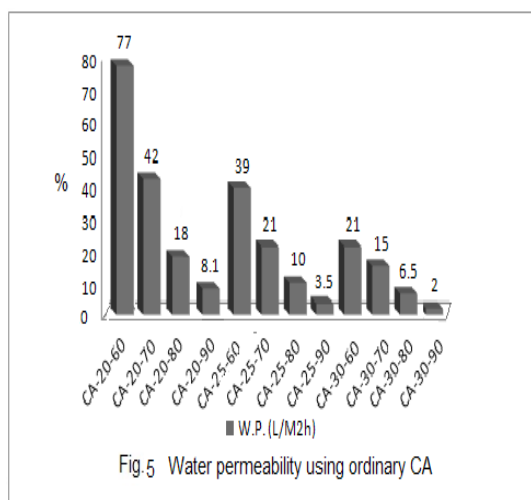
**Fig. 3.** A scanning electron microscope photograph for the woven fabric sample with PTFE-NCA membrane on the top surface.



**Fig. 4.** Back side of the woven fabric sample with PTFE-NCA membrane on the top surface with two magnifications.

the inundation technique from 20 and 25 weight percent of polymer concentrations. Applying the annealing temperature range 60-90°C, the thickness of the dry films were about 60-80  $\mu\text{m}$  depending on the initial concentration of the polymer in the dope solution. SEM graphs (Fig.1-4) using different magnifications indicate the asymmetrical structure for the produced materials composed of a top skin layer withstand by an open spongy like composition. Changing of both parameters include sturdy alterations of the permeability degree of the yield membranes [21].

Increasing the permeability with decreasing of the annealing temperature and concentration of the polymer indicating the untying of the produced structure and altering the distribution of the pore size from RO to NF materials. Meanwhile, maximum operating pressure for CA-20-60 was 0.8 Mb as a result of decreasing mechanical strength as shown in Fig.5. The other samples were tested up to 1.5 Mb. to seek for a connection between mechanical strength and high flux, the study restricted on materials those annealed between 70 and 80°C.



**Fig. 5. Water Permeability using Ordinary CA** (The first number refers to CA concentration as (g/l) and the second refers to the annealing temperature after casting in °C).

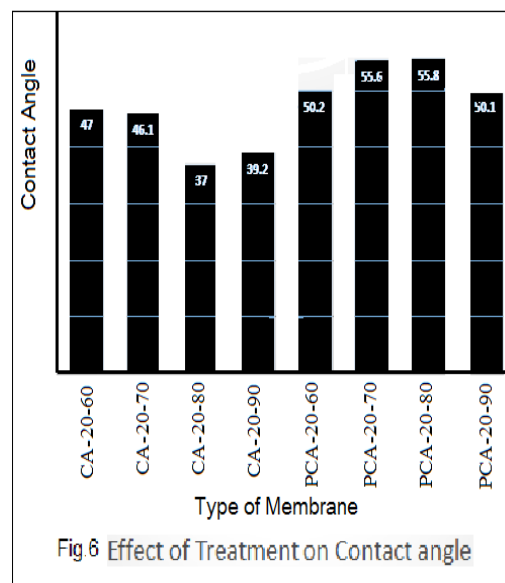
#### PTFE-NCA membranes Characterization

PTFE-NCA combined membranes or simply (PCA) were obtained by overlaying a very fluffy layer of PTFE over the surface of NCA supports as shown by the SEM micrographs in Fig. 3a-d for CA-22-80 and PCA-22-80. The adaptation yields to increased uniform and smoother surfaces. Although, the SEM analytical data indicate a small pore hindrance of the top layer structure that had to be produced in a higher or lower penetration of PTFE within the NCA support morphology.

On comparison between the values of water contact angles produced for unchanged and membranes indicated in Fig. 6 proof that the surface amended by the PTFE overlying. The increased values presented for the PCA samples meet with the PTFE hydrophobic nature. Also, the outcome refers to a decreased contact angle for membranes produced from polymers with higher concentrations. Such behavior is related to how denser the structure of the upper layer surface is. Therefore, no clear difference was noticed with the annealing degree. It illustrates that such parameter affected on the film morphology more than on the surface structure.

#### Desalination Behavior

Comparing CA supports (CA-C-T) and the produced membrane (PCA-C-T) for the desalinating brackish water is illustrated in Fig. (6) Ongoing from pure to brackish water, the permeation rate declined to 10-20 % for NCA supports and produced composite membranes, consequently. It must be obvious that increment is greater for the membranes those possessing the narrow pore diameter (CA-22-80 & PCA-22-80).



**Fig 6 Effect of Treatment on Contact angle**

The best expression for the obtained data is the T.D.S % rejection. As predicted the production circumstances influence sturdily the salt removal performance. Both factors of increased annealing temperature and concentration of polymer improved the salt rejection value from 66 to 90% for CA membranes. The surface alteration with PTFE increased the retention (PCA membranes). The increased value was remarked for the membranes performed at 70°C. On the other hand, frequently no variation was noticed for



**TABLE 2. Chemical analysis of brackish water sample after desalination using PTFE-NCA at 60°C with 20 ppm concentration.**

| Anion                         | Concentration | Cation                     | Concentration |
|-------------------------------|---------------|----------------------------|---------------|
| HCO <sub>3</sub> <sup>-</sup> | 98            | K <sup>+</sup>             | 12            |
| Cl <sup>-</sup>               | 57            | Na <sup>+</sup>            | 56            |
| NO <sub>3</sub> <sup>-</sup>  | 22            | Ca <sup>2+</sup>           | 23            |
| SO <sub>4</sub> <sup>2-</sup> | 38            | Mg <sup>2+</sup>           | 18            |
| Total Anion concentration     | 215           | Total Cation concentration | 109           |

materials produced at 80°C. It was suggested that the selection resulted from the NCA support in the case of the narrower pore structure. Table 2 illustrates the decrease in TDS for the untreated brackish water and after desalination using the PTFE-NCA composite, about 80% reduction in all anions and cations was found assuring the enhanced performance of the produced product.

### Conclusion

CA-membranes reinforced with PTFE sheet were utilized as brackish water desalination membranes, different parameters were used to obtain the higher performance membrane such as dope solution concentration as well as the annealing temperature. The results indicated that the higher performance was obtained with composite membrane prepared with 20% and 90°C. The study assured that using reinforced PTFE increased the composed membrane performance towards Water permeability, flux and salt rejection 20% more than the normal CA-membranes.

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## تحلية المياه باستخدام أغشية نانوية من خلات السليولوز المدعمة بعديد ثلاثي فلورات الإيثيلين

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حيث تم تدعيم الأغشية المكونة من خلات السليولوز بشرائح من عديد ثلاثي فلورات الإيثيلين وإستغلالها كأغشية مزيلة لملوحة مياه الآبار ، وقد تمت دراسة العوامل المختلفة المؤثرة علي سير التفاعل مثل تركيز محلول خلات السليولوز ودرجة حرارة التفاعل وغيرها من العوامل وقد اوضحت الدراسة من خلال النتائج المعتمدة علي قياس التركيب البنائي للمنتج باستخدام الأشعة تحت الحمراء و قياس دوران الإلكترون الميكروسكوبي SEM بالإضافة لقياس نفاذية الأغشية للمياه وفيض المياه وزاوية التلامس وكلها قد أكدت علي ان أداء الأغشية المكونة من خلات السليولوز المدعم بشرائح من عديد ثلاثي فلورات الإيثيلين قد فاقت أداء الأغشية الغير مدعمة بأكثر من ٩٠٪ زيادة في الأداء وبخاصة تلك الأغشية المحتوية علي محلول بتركيز ٨٠ الي ٩٠ جم/لتر عند درجة حرارة ٢٠°م.