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Enhanced oil-water separation using polyvinylchloride membranes modified with polymeric additives

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Abstract

Large volumes of oily wastewater are now being produced from a variety of sources. Separating stable emulsified oil particles from water is the most difficult part of treating oily wastewater. Generally, due to their ease of use, low cost, and high flexibility; polymeric membranes are critical in these processes. Many kinds of chemicals are added to a based polymer to increase both its hydrophilicity and its properties as enhancing pure water flux (PWF). This study provides an example of the phase inversion approach used to produce a PVC membrane. PVC has been modified by adding polymeric additives like polyvinylpyrrolidone (PVP) in order to increase both permeation flow and fouling resistance, also in this paper we compare between lab chemical membrane and commercial chemical membrane on the hand of their fluxes, rejection and characterization. Mechanical strength, porosity, scanning electron microscopy (SEM), Fourier Transform Infrared (FTIR), and water contact angle measurement were used to characterize and assess the improved PVC/PVP membranes. The membranes were subsequently tested at a lab size in a cross-flow system with synthetic oily wastewater as the input.

1.   Introduction

Oily wastewater is water that has a significant amount of oil in it, including hydrocarbons, fats, and petroleum components like petrol, diesel oil, and kerosene. [1, 2]. Recently, numerous businesses, including petrochemical enterprises, food and steel companies, textile facilities, and petroleum refineries, discharge a significant amount of oily wastewater effluents into seas and rivers [3]. In actuality, the uncontrolled discharge of oily wastewater has a number of negative effects on the environment, including the contamination of surface water, ground, marine, and soil pollution, as well as air pollution brought on by the evaporation of oil into the atmosphere and the presence of hydrocarbons [4, 5]. Petroleum hydrocarbons, polyaromatic compounds, and phenols in oily wastewater, in addition to being poisonous, can inhibit plant and animal growth and increase the risk of cancer in humans [6, 7]. There are three categories for the size of the oil particles in oily wastewaters. According to the size of the dispersed phase, oil/water mixes can be divided into three categories: free oil-water mixtures (>150 mm), oil-water dispersions (20-150 mm), and oil/water emulsions (20 mm). [8]. The oil-in-water emulsion, one of several oil/water systems, has developed into a substantial environmental treatment due to its tiny droplet sizes (20 m) [9]. There are numerous conventional oily wastewater treatment methods include flotation [10], Skimming [11], gravity settling [12], coagulation [13], flocculation [14]. However, these techniques have a number of drawbacks, including the generation of secondary contaminants, high energy consumption, low efficiency, unfeasible operating costs, corrosion, large equipment sizes, a need for a lot of space, re-pollution, etc.[15, 16]. Adsorption is also considered as a conventional separation technique, however, it has its limitations including being time-consuming, inapplicable for oil/water emulsion separation, and complex operational processes [17]. More advanced separation techniques include the use of membranes. Since membrane technology has gained wide attention over the last thirty years with several methods being used in various industrial fields such as ultra-pure water production, water desalination, product recycling and wastewater treatment [18], due to its easy operation, cost-effectiveness and low energy cost [18, 19]. Ultrafiltration membrane (UF), is one of many membrane technologies that gained recognition as an amazing method in the wastewater systems of refineries due to its ability to remove emulsified oil droplets and other organic impurities. Its pore

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diameters are typically 2–50 nm [20], also UF membrane is known as filtration-induced macro solute or particle deposition, which is often reversible, non-adhesive fouling, where the accumulation of cell debris, cells and other rejected particles are observable on the membrane's top surface. It manifests as exterior fouling or cake development [21]. However, fouling has a significant issue with UF membranes that can be brought on by the deposition of an oil layer on the membrane surface or by oil droplets blocking membrane pores, which results in a significant flux decline [22]. This may be caused by a variety of things, such as a cake-like layer of deposition on the membrane surface, internal adsorption, and pore-blocking deposition [23]. Other elements that affect membrane fouling include the membrane's pore structure, operating and process parameters, as well as surface features. Therefore, the practical way to lessen fouling and its effects like retention decline and flux is to properly tailor the desired membrane material. Although the hydrophilic membranes are found to have a lower propensity for fouling, their typical thermal and chemical stabilities are constrained [24]. Polymeric membranes typically play a significant part in these processes due to their simple, affordable processing and high flexibility [7]. Since last year, many approaches have been used to lessen the phenomena of fouling, which can be divided into four basic categories: improving operating conditions, pretreating feed, cleaning techniques, and membrane modification [22]. The latter has drawn a great deal of interest, and numerous studies have been carried out to improve the antifouling capabilities of polymeric membranes. Antifouling membrane has been prepared using three methods: organic nanoparticles being incorporated into the membrane matrix [25, 26], modification of membrane surface [27, 28] and blending of different polymers [29, 30]. One of these strategies is blending polymers together since it is the most practical and convenient technique to improve the antifouling capabilities and performance of polymeric membranes. It is also the most practical from an operational and financial standpoint [31, 32]. Due to its intriguing physical, chemical, and thermal stabilities, superior mechanical strength, long lifespan, low cost, and solubility in various solvents like tetrahydrofuran (THF), dimethylformamide (DMF), N-methyl pyrrolidone (NMP), and N,N-dimethylacetamide (DMAc), polyvinyl chloride (PVC) has received a lot of attention recently for the preparation of oily wastewater treatment membranes [33, 34]. However, due to the PVC membrane's high

hydrophobicity and ease of fouling, its usage in wastewater treatment operations has been restricted. Numerous modification techniques have been investigated to improve the antifouling and hydrophilicity of PVC membrane. For instance, surface grafting was used to alter the PVC membrane's surface [35] and surface coating [36] procedures that produced membranes that were both hydrophilic and fouling resistant. Inorganic nanoparticles like ZnO have been explored by certain researchers as being embedded [37], TiO2 [38] and SiO2 [39] into PVC membranes . In comparison to pristine PVC membrane, the final membranes in all of these works exhibit better antifouling capabilities and improved water flux. However, organic/inorganic membranes encounter a problem with particle agglomeration at higher nanoparticle contents, which restricts their use. A fascinating, adaptable, cost-effective, and simple way for creating polymeric membranes with better characteristics is polymer blending [32, 40]. PVC has been combined with other polymers in recent years to create polymeric membranes with improved antifouling and flux qualities. Peng and Sui created PVC/PVB (poly vinyl butyral) blend membranes with PVC/PVB ratios ranging from 0:10 to 9:1, and the results showed that adding PVB boosted the membranes' water flow and hydrophilicity while somewhat reducing their rejection of egg white protein [40]. In the presence of polyethylene glycol 600, Krishnamoorthy et al. developed PVC/CA mix ultrafiltration membranes and discovered that as the PVC percentage in the dope solution grew, the water flux of the membranes increased while rejection dropped. Although pure water flux reduced from 112.5 LMH for PVC membrane to 95.2 LMH for PVC/PS blend membrane with a 14:6 ratio, Alsalhy created PVC/Polystyrene blend membranes in a different investigation, and it was demonstrated that the rejection of blend membranes was higher than that of pristine PVC membrane [41]. It is usually common to add various compounds to the phase inversion procedure used to make membranes in order to manage both chemical interactions and structural characteristics [42, 43]. To improve the characteristics of the membranes, PVP additive is added to PVC-based polymers. Actually, by adding PVP additive with a very similar pore size distribution, the membranes increase their permeability [44]. Three factors may be to blame for this: an increase in pore density, a decrease in the effective thickness of the dense layer caused by macro gaps in the support layer, and an increase in the

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hydrophilicity of the membrane and pore surfaces. The goal of this study is to provide an economical solution for oil-water emulsion separation using membranes because the material is affordable and has antifouling capabilities.

2.   Experimental work

2.1. Materials

All chemicals used in the present work are listed in table (2.1). Commercial polyvinyl chloride (PVC) and commercial polyvinyl-pyrrolidone (PVP) purchased from El Geish Street, Cairo, Egypt. Lab chemical polyvinyl chloride (PVC) and lab chemical polyvinyl-pyrrolidone (PVP) provided by Simga-Aldrich Merck (USA). Sodium laury sulphate (SLS) purchased from from Merck help Olive oil to break up and prepare oil in water emulsion easily. N, N-Dimethyl-formamide (DMF) are used for preparation membrane by phase inversion method. Citric acid and sodium hydroxide help in chemical cleaning as simple acid and simple base.

Table (2.1): Properties of chemical Used

Chemicals	Compound	Mwt.
Polyvinyl chloride (PVC)	C_2H_3CL	3000-4000
Polyvinyl-Pyrrolidone (PVP)	C_6H_9NO	24000
N, N-Dimethyl-formamide (DMF)	C_2H_7NO	73.09
Sodium laury sulphate (SLS)	$NaC_{12}H_{25}SO_4$	288.38
Citric acid	$C_6H_8O_7$	36
Sodium hydroxide	NaOH	40

2.2. Membrane preparation

Modified PVC membranes were prepared using PVP as a pore former and PVP composition is 3 wt% with M_{wt} equal 24000 g/mol, also the based polymer PVC is 17 wt% with M_{wt} equal 3000-4000 g/mol. Flat sheet PVC membranes were made by using water as a non-solvent during the phase inversion process. In order to make the casting solution, PVC and the necessary pore former additive were dissolved in N, N-Dimethylformamide (DMF), which made up 80% of the mixture. The casting solution was constantly agitated for 24 hours until a clear, homogeneous solution was achieved. Using an Elicometer thin film applicator, the solution was then cast onto a glass plate for a thickness of approximately 200 m. The glass plate was then immediately submerged for 24 hours in a distilled water bath maintained at 20°C in order to replenish the remaining DMF. The cross-flow UF tests used in this work called for a certain section of the modified PVC membrane to be taken out.

2.3. Oil / water emulsion preparation

Using distilled water and commercial-grade olive oil, a stable emulsion concentration of 2000 ppm of oil-water mixture was created in the lab. First, 500 ml of distilled water was combined with 2 g of olive oil and 1 g of the anionic surfactant SDS, which serves as an emulsifier. In a volumetric flask, the solution was diluted to a volume of 1000 ml. The combination was stirred with a magnetic stirrer tank for two hours at a speed of 750 revolutions per minute till the milky white oily water was determined to be stable because the turbidity of the emulsion's surface was found to be 165 NTU and its bottom was almost discovered to be 163 NTU. Assuring the concentration of oil in water during each cycle of the filtration process, the stable oil-water emulsion was subsequently held at room temperature.

2.4. Characterization of modified PVC membrane

Contact angle (CA) was used to analyze the contact angle of produced membranes in order to determine how hydrophilic they were. Using water droplets positioned in five different locations, the incident and receding angles were calculated to determine the equilibrium water contact angle. The water contact angle of each membrane was determined by averaging the five observations. FESEM was used to visualize the top surface morphology and cross-section morphology of additives applied to commercial and laboratory chemicals of PVC membranes. FTIR stands for Fourier transform infrared spectroscopy. Fourier transform infrared spectroscopy (FTIR) record infrared spectra between wavelength 1730 and 2853 cm^{-1} in order to identify the functional group, strength mechanically and porosity. A tensile testing machine was used to assess the produced membranes' mechanical strength. Porosity could also be measured by measuring the permeability of the membrane sample and studying the permeate of flows and rejections of oil to show how well the membrane performed.

2.5. Experimental setup and methodology

We will illustrate the set-up of equipment, procedure of experiment and operational conditions.

2.5.1. Experimental set-up

We investigate pure water flux (PWF) and oily wastewater filtration using a lab scale cross flow system. The system consists of an ultrafiltration (UF) membrane since the filtration cell has a surface area of 17.349 cm2, a feed reservoir, a pump, and a pressure gauge so that the pressure is maintained at 1 bar throughout the entire process. The schematic of the cross-flow system employed in this paper is shown in figure (2.1). In table (2.2), the operational conditions are displayed.
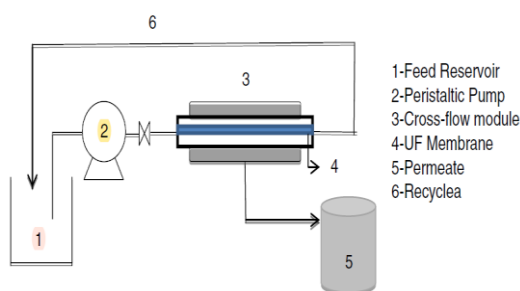

1-Feed Reservoir
2-Peristaltic Pump
3-Cross-flow module
4-UF Membrane
5-Permeate
6-Recyclea

Fig (2.1): Schematic representation of cross-flow UF.

2.5.2 Experimental methodology

Initially, the emulsion is prepared by adding 1 gm of sodium laury sulphate to 2000 ppm oil concentration and mixing it throw magnetic stirrer with speed 750 rpm for 2 h until the emulsion become homogenous. We check the homogeneity of emulsion by measuring the turbidity on top of emulsion and it was found to be 165 NTU by turbidity measurement, the turbidity on bottom was nearly the top and found to be 163 NTU. We connect the emulsion with peristaltic pump to pressure it at constant pressure 1 bar, the feed passed throw cross flow UF membrane that has area about 17.349 cm^2 and we get the permeate.

2.6. Factor affecting membrane performance

In this paper we study the factors that affect the process, the most important two factors that affect process were the concentration of feed emulsion and the temperature of the emulsion. We have done the operation at liquid oil concentration 1000, 2000 and 4000 ppm and recorded the effect of this in fluxes and rejection of oil. Also, we changed the temperature of feed emulsion and done the process at room temperature, 10°C and 80°C. The effect of temperature is more than the effect of concentration of feed emulsion because the rejection of oil from oily waste/water reach to nearly 99% more than effect of different concentration, also the fluxes reach to 26.5 LMH for laboratory chemical membranes but reach to 17 LMH for commercial chemical membrane more than effect of concentration which fluxes reached to 9.9 and 9.2 LMH for both lab and commercial chemical membrane.

2.7. Membrane fouling and chemical cleaning

We researched membrane fouling because it occurs when pores are partially or completely blocked by the adsorption of emulsion's continuous or dispersed phases, or when one or more phases accumulate on the membrane surface due to concentration polarization. This occurrence causes a sharp drop in flux and worsens the flow rate of the hydraulic system as a whole. Chemicals with an acidic or alkaline base are frequently used to improve membrane performance. For cleaning membranes soiled by oil/water emulsions with a concentration of 0.1 M, the most popular cleaning agent is NaOH, also we clean the fouled membrane with simple acid such as citric acid with concentration 0.15 M and record the recovery of declined pure water done due to fouling.

2.8. Membrane performance

Membrane performance is determined by calculating fouling properties and water flux percentage. PWF of membranes was determined by cross-flow filtration system almost at pressure of 1.5 bar using Equation (1) [15].

$$J\_0 = v/(A * \Delta t) \quad (1)$$

where A is the membrane area in (m^2), J_0 is the pure water flux in (L/m^2.h), t is the time in (h), and v is the volume of water that has been collected in (L). The membrane modulus was mounted to the oily wastewater feed tank after measuring PWF. After around three hours of membrane filtration, the water flux system was rejoined with the modulus to calculate the PWF, but after fouling (J_1) at the same Equation (1). Finally, a sponge was used to mechanically remove the cake layer from the membrane, and the membrane was then washed with deionized water. The membrane was then kept in a modulus and reconnected to the water tank, and the PWF after rinsing (J_2) was calculated using Equation (1) as well. Knowing (J_o), (J_1), and (J_2) fouling properties of the membranes were calculated using the following equations [45, 46].

$$TFR = \left(\frac{J_1 - J_0}{J_1}\right) * 100$$
(2)

$$RFR = \left(\frac{\bar{J_2} - J_0}{\bar{J_1}}\right) * 100$$
(3)

$$IFR = \left(\frac{\overline{J_1} - J_2}{J_1}\right) * 100$$
(4)

$$FRR = \left(\frac{J_2}{J_1}\right) * 100$$
(5)

where TFR could be a add up to fouling proportion, RFR could be a reversible fouling proportion, IFR is an irreversible fouling proportion, and FR may be a flux recuperation. These proportions are utilized to examine the anti-fouling execution of the manufactured membranes since the higher FRR values and the lower DR intended the higher antifouling belongings of the membrane in oil/water separation performance [47]. The foremost common examination to assess treated water quality and membranes performance in the oily wastewater treatment operations is using UV spectrophotometer [15, 48] and turbidity measurement [49] only when preparation of emulsion.

3. Results and discussion

3.1 Characterization of the membranes

The mechanical strength, porosity, scanning electron microscopy (SEM), FTIR, and water contact angle measurement of the improved PVC/PVP membranes were used to characterize and assess them.

3.1.1 Mechanical strength

We measured the tensile strength after measuring force and extension from the device, the tensile strength for lab chemical membrane was about 42.12766 MPa, but the tensile strength for commercial chemical membrane was about 32.75461 MPa. Table (3.1) illustrates the mechanical properties of both lab and commercial chemical membrane.

Table (3.1): Mechanical properties for two types of membrane

Type of membrane	Force (N)	Extension (mm)	Thickness (mm)	Average thickness (mm)	Tensile strength (MPa)
Lab chemical membrane	99	14.663	0.087 0.093 0.102	0.094	42.1266
Commercial chem membrane	119.8	19.059	0.147 0.143 0.149	0.0146 3	32.75461

3.1.2 Porosity measurement

We calculated the porosity of lab and commercial membrane and found that porosity of lab chemical was 0.2755 but that of commercial chemical membrane was found to be 0.0937. Table (3.2) illustrates the porosity of both types of membrane since permeability could be calculated from the following equation 135.5/time (sec). Time calculated from the equipment directly and then porosity calculated through equation PC/r^2 since P is permeability, C is constant equal 2 and r^2 equal 6.25 cm^2 from device *3.1.3 Contact angle (CA)*

We analyzed contact angle for both pristine PVC lab and PVC commercial chemical membrane and found that contact angle for lab chemical membrane is less than commercial chemical membrane since it was found to be 66.9 O for lab but was about 86.4 o for commercial chemical membrane. We concluded that hydrophilicity of lab chemical is more than commercial chemical membrane as shown in figure (3.1).

CA left 70.1°   CA left 66.9°   CA left 64.7°

CA right 70.1^0 CA right 66.9^0 CA right 64.7^0

a)   CA left 87.7°   CA left 86.4°   CA left 84.5°

CA right 87.7^0 CA right 86.4^0 CA right 84.5^0
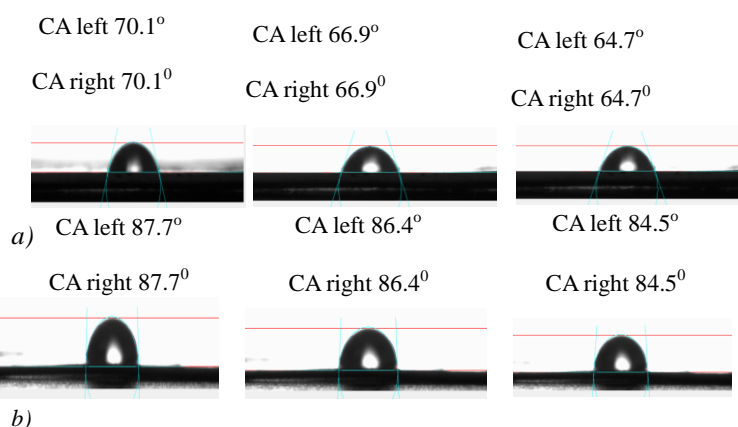
b)

Figure (3.1): Contact angle for both a) lab and b) commercial chemical membrane from different three angles.

Type of membrane	Time (sec)	Vol (ml)	Permeability	Porosity Q_c
Lab	157.4	110	0.86086	0.2755
Commercial	462.7	120	0.2928	0.0937

Table (3.2): Porosity of membranes

3.1.4 Scanning electron microscopy (SEM)

The mineralized membrane's cross-sectional scanning electron microscopy (SEM) image shows a finger-like porous structure with an even distribution of components throughout the membrane, since commercial chemical membrane has less voids than lab chemical membrane, also for top surface structure the commercial is more closed opening than lab so the results for lab chemical membrane is slightly better than commercial chemical membrane as shown in figure (3.2).
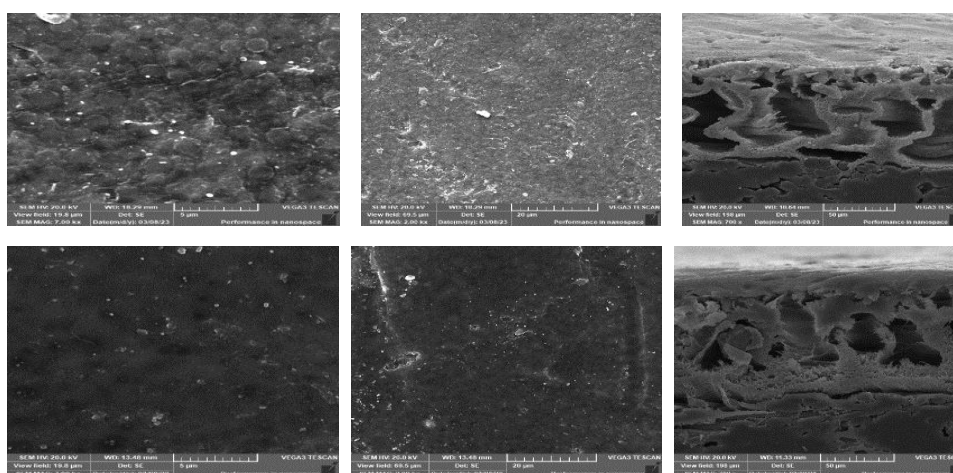

Figure (3.2) SEM analysis for both lab chemical membrane in the top and commercial chemical membrane in bottom from different scales illustrating surface and cross section morphology.

3.1.5 Fourier transform infrared spectroscopy (FTIR)

Slightly intensified broadband between 1730 and 2853 cm^{-1} for the neat PVC for lab and commercial can be observed, also wavelength between 1744 and 2853 cm^{-1} for coated membranes, which was attributed to the O-H stretching vibration ascribed to the hydroxyl groups in TA-Fe. As a result, PVC coated showed significantly reduced contact angle (44.3^o) compared to neat PVC of (64.7^o) as a result of the hydrophilic nature of O-H group.

3.2 Membrane filtration results

We will show the experimental results obtained to separate oil from oily waste-water using both lab chemical membranes and commercial chemical membranes and compare between them (modified PVC membrane).

3.2.1 Lab chemical membrane results

The composition of the prepared lab chemical membrane is PVP as a polymeric additive in the composition of 3% wt with M_{wt} equal 24000 g/mol along with based polymer PVC of 17 % wt with M_{wt} equal 3000-4000 g/mol. During experimentation we calculated the flux of product done and the rejection of oil. The figure (3.4) shows the rejection percentage of oil from oily
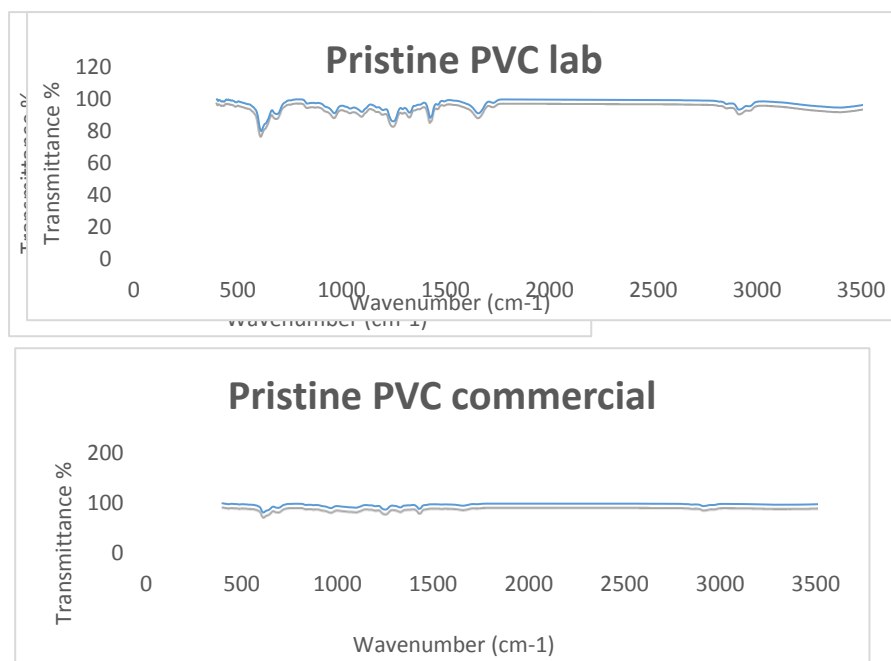
Pristine PVC lab

Pristine PVC commercial

Figure (3.3) FTIR analysis for both lab and commercial membranes rejection for ML.

Conc-Reject for commercial (2000 ppm)

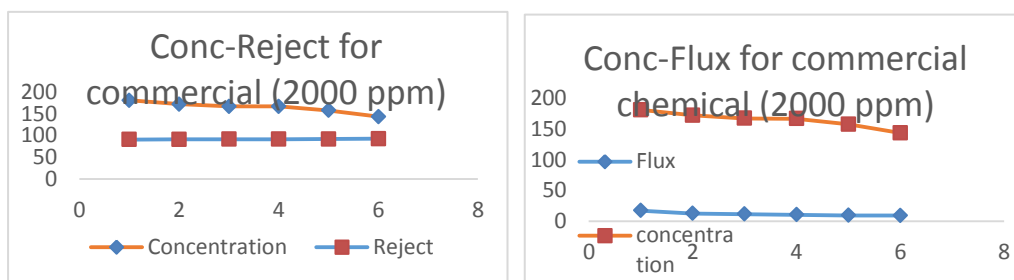**Conc-Flux for commercial chemical (2000 ppm)**

Figure (3.4): The effect on oil concentration in permeate & decline of flux, also effect on oil waste/water emulsion concentration 2000 ppm and the flux of emulsion through the experiment and its effect on volumetric flow rates.
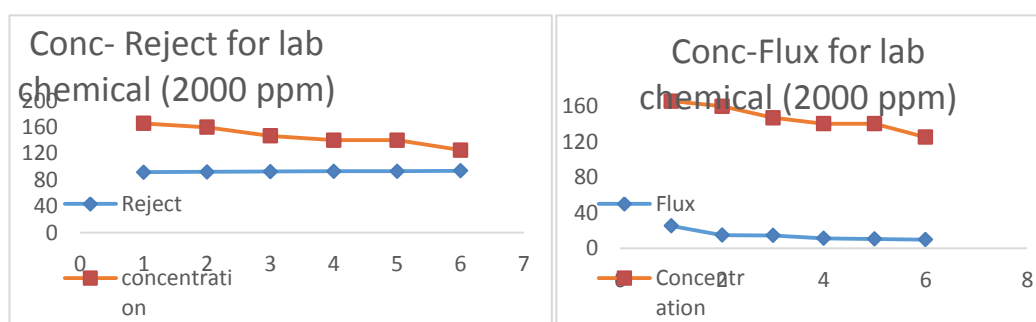
Conc- Reject for lab chemical (2000 ppm)

Conc-Flux for lab chemical (2000 ppm)

Figure (3.5): The effect on oil concentration in permeate & decline of flux, also effect on oil rejection for MC.

waste/water emulsion concentration 2000 ppm and the flux of emulsion through the experiment and its effect on volumetric flow rates.

The high rejection of oil due to high hydrophilicity of PVP/PVC enhanced membrane since concentration of oil from emulsion is reduced from

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2000 ppm to 125 ppm and the highest initial flux was found to be 25.362 Lm-2 h-1 for PVP/PVC membrane but after compaction the steady state flux reached 9.914 L m-2 h-1 due to fouling occurring and blocking of oil droplets of membrane pores, also we found that rejection of oil has increased until reaching up to 93.749%.

3.2.2 commercial chemical membrane results

The same composition of commercial chemical membrane as composition for lab chemical membrane was used. Figure (3.5) shows the rejection percentage of oil from oily waste/water emulsion concentration 2000 ppm and the flux of emulsion through the experiment and its effect on volumetric flow rates

We found that the concentration of oil in permeate reduced from 2000 ppm in commercial chemical membrane to 143.878 ppm with rejection percent 92.8061 %, also we found that rejection of oil is increased until reaching 92.8061 % and the flux of permeate reduced to 9.92224 LMH.

3.3 Factor affecting separation process for lab and commercial chemical membrane

We investigated how emulsion concentrations at low and high levels affected the separation process. We also studied the effect of temperature of feed stock of emulsion at either low or high temperature

3.3.1 The effect of concentration of emulsion (2000 ppm) on separation oil using lab and commercial chemical membrane

We studied the effect of emulsion concentration (2000 ppm) on fluxes and rejection For lab chemical membrane we found that the rejection of oil reached to 93.749 % but the flux of it reached to 9.91412 LMH and for commercial chemical membrane we found that the rejection of oil increased until reaching 92.806 % but the flux of oil reached to 9.2224 LMH as shown in figure (3.6). We abbreviated flux for lab (M1), flux for commercial (M2), rejection for lab (M3) and rejection for commercial (M4) for all the next
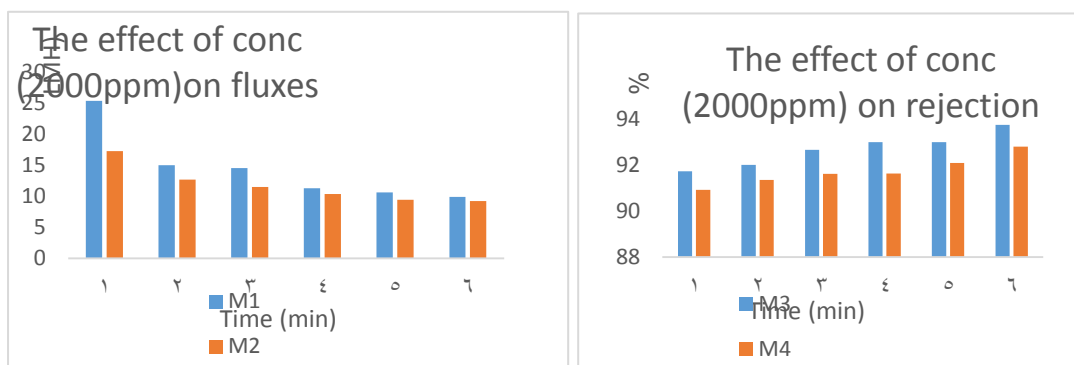

Figure (3.6): Comparison between M_L and M_C membrane for fluxes and rejection (2000 ppm for emulsion conc).
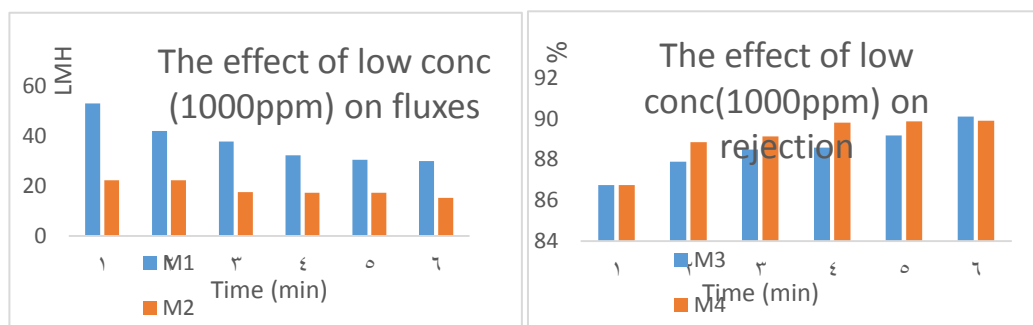

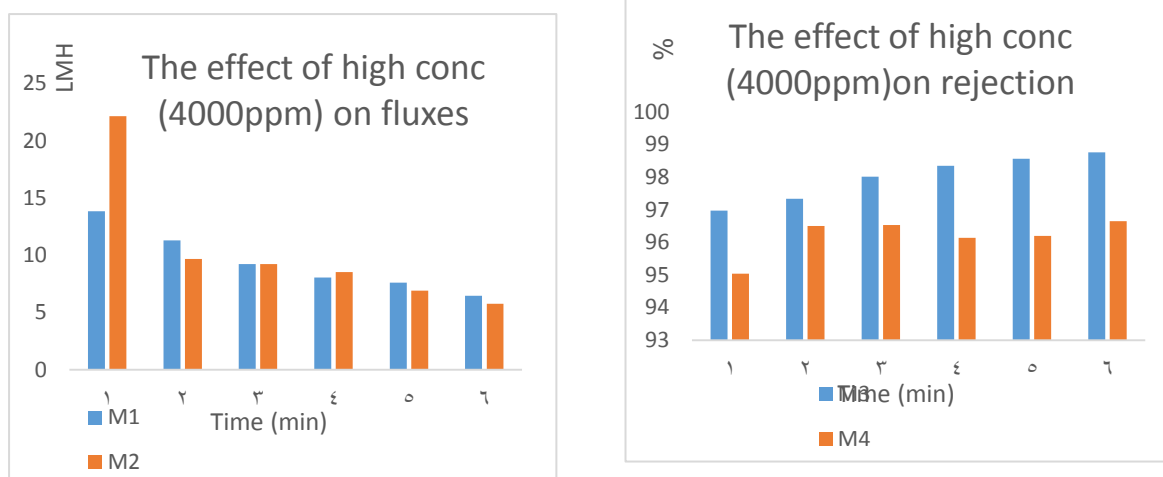Figure (3.7): Comparison between M_L and M_c membrane for fluxes and rejection (1000 ppm for emulsion conc).

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Figure (3.8): Comparison between M_L and M_C membrane for fluxes and rejection (emulsion concentration 4000 ppm).

3.3.2 The effect of concentration of emulsion (1000 ppm) on separation oil using lab and commercial chemical membrane

When changing concentration of feed emulsion to 1000 ppm we found that the rejection of oil for lab chemical membrane has reached to 90.1141% and the flux was found to be 29.973 LMH as shown in figure (3.7), but rejection for commercial chemical membrane has reached to 89.924 % and the flux was about 15.217 LMH.

3.3.3 The effect of concentration of emulsion (4000 ppm) on separation oil using lab and commercial chemical membrane

When changing concentration of feed emulsion to 4000 ppm we found that the rejection of oil for lab

chemical membrane has reached to 98.7643% and the flux was found to be 6.4557 LMH, but rejection for commercial chemical membrane has reached to 97 % and the flux was about 5.764 LMH as shown in figure (3.8).

3.3.4 The effect of high temperature ($T=80^oC$) on separation oil using lab and commercial chemical membrane

When changing temperature of feed emulsion to 80^oC as shown in figure (3.9) we found that the rejection of oil for lab chemical membrane has reached to 99.5608 % and the flux was found to be 26.5145 LMH, but rejection for commercial chemical membrane has reached to 89.924 % and the flux was about 17.062 LMH.
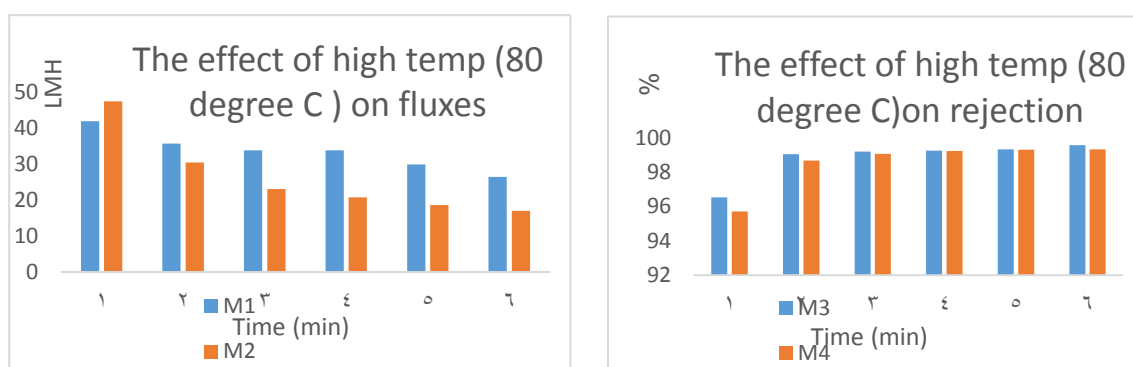

Figure (3.9): Comparison between M_L and M_C membrane for fluxes and rejection (emulsion temperature 80^oC).

3.3.5 The effect of low temperature (T=10°C) on separation oil using lab and commercial chemical membrane

When changing temperature of feed emulsion to 10°C as shown in figure (3.10) we found that the rejection of oil for lab chemical membrane has reached to 99.3079 % and the flux was found to be 9.2224 LMH, but rejection for commercial chemical membrane has reached to 98.57223 % and the flux was about 7.8391 LMH.

3.4 Comparison between fouling and chemical cleaning for lab and commercial membranes

We compared between effect of fouling of lab chemical membrane and commercial chemical membrane by decline of flux for both of them.

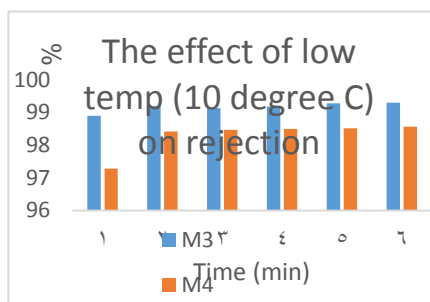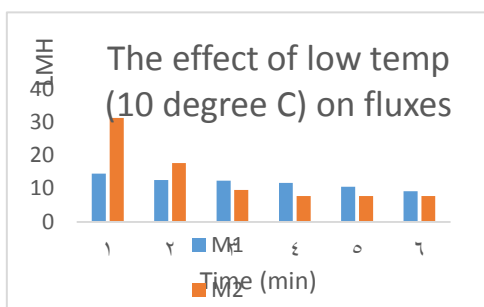*3.4.1 Fouling effect* For lab chemical membrane the

pure water in initial state before the process was found to be 55.3346 LMH and after fouling occurs the PWF reached to 20.7505 LMH as shown in figure (3.11). But for commercial membrane the flux of pure water in initial state before the process was found to be about 44.9594 LMH but it reached after fouling to 17.2921 LMH.

3.4.2 Chemical cleaning

Compare between fluxes of both Lab and chemical membrane after cleaning.

3.4.2.1 Chemical cleaning with simple acid as citric acid C6H8O7 (0.15M)

For commercial chemical membrane flux reached after chemical cleaning with citric acid to 24.20889 LMH, but lab chemical membrane after chemical cleaning with citric acid reached to 31.125 LMH as shown in figure (3.12).

Figure (3.10): Comparison between M_L and M_C membrane for fluxes and rejection (emulsion temperature 10°C).
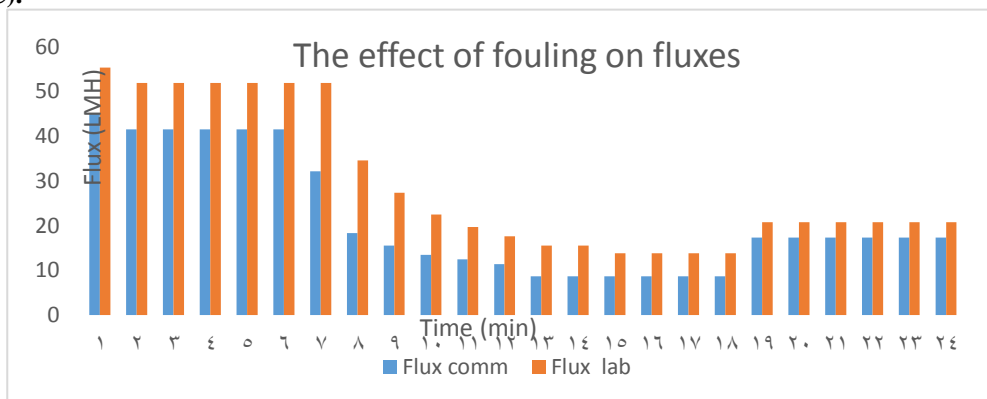

Figure (3.11): Comparison between fouling for both types of membrane

3.4.2.2 Chemical cleaning with simple base as sodium hydroxide (0. 1M)For commercial chemical membrane flux reached after chemical cleaning with sodium hydroxide to 27.6673 LMH, but lab chemical membrane after chemical cleaning with sodium hydroxide reached also to 27.6673 LMH as shown in figure (3.13).
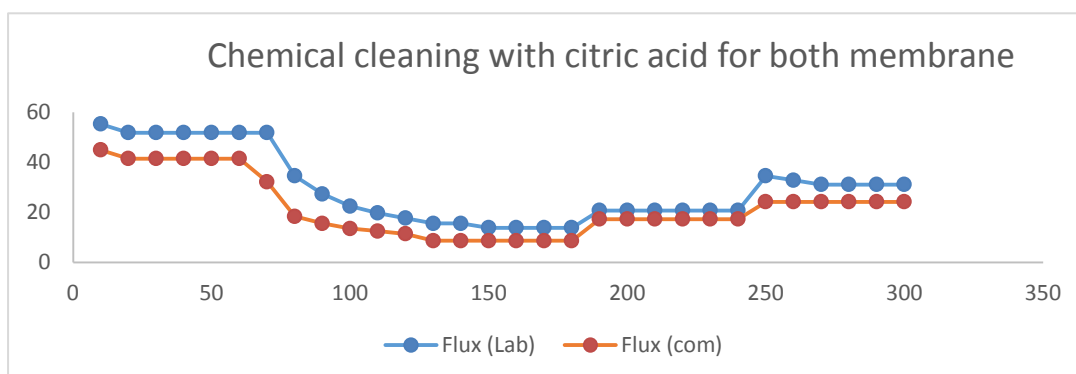
Figure (3.12): Chemical cleaning with citric acid for both lab and commercial chemical membrane
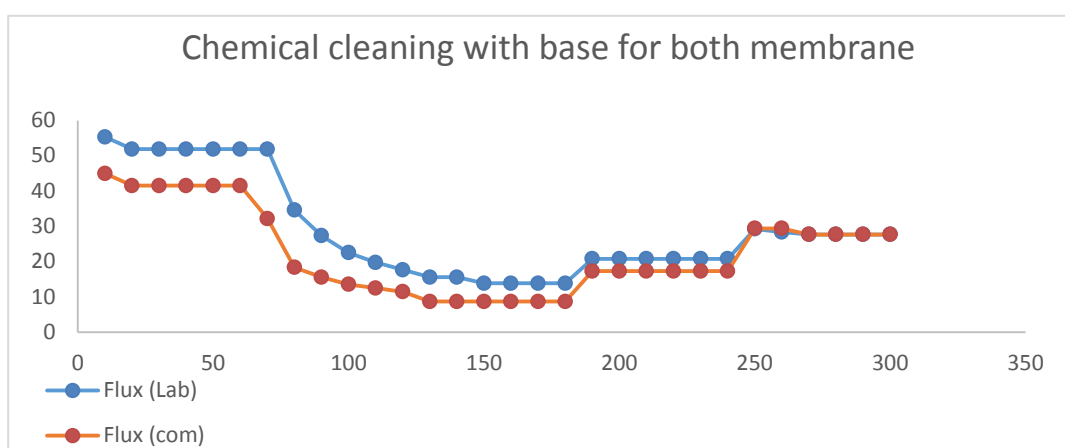

Figure (3.13): Chemical cleaning with sodium hydroxide for both lab and commercial chemical membrane.

4. Conclusion

Phase inversion was used in this study to create commercial and lab chemical PVC/PVP membranes for the treatment of oily waster. Due to its high hydrophilicity, PVP has been used to solve a number of PVC-related issues, including the fouling of PVC membranes and matrix aggregation. In this research, the following points have been investigated:

(1) Compared the performance between lab chemical membrane (M_L) and commercial chemical membrane (M_c), pure water flux decreased by 60.9% and 46.67% for M_L and M_c, respectively

(2) The standard emulsion concentration used was about 2000 ppm. The concentration of oil is reduced by 93.75% and 92.806% for M_L and M_c

used, si (3) By studying the factors affecting of separation process such as concentration and temperature of emulsion, first for M_L the flux reduced by 43.47% and 53.33%, also the rejection reached to 90.114% and 98.764% for low concentration content (1000 ppm) and high concentration (4000 ppm), respectively. When increased and reduced temperature of emulsion for about (80^0C & 10^0C) the rejection reached the higher percentage about 99.5608 % and 99.3079 %, also flux reduced by 36.8% and 36.508 %, respectively for M_L.

4. (4) for M_C the flux reduced by 31.958 % and 73.95 %, also the rejection reached to 80.924 % and 79% for low concentration content (1000 ppm) and high concentration (4000 ppm), respectively. When increased and reduced temperature of emulsion for about (80^0C & 10^0C)

the rejection reached high percentage about 99.334 % and 98.57 %, also flux reduced by 64% and 74.9 %, respectively for M_C.

(5) By studying the effect of fouling and chemical cleaning since for M_L the pure water in initial state before the process was found to be 55.3346 LMH and after fouling occurs the PWF reached to 20.7505 LMH, but for M_C the flux of pure water in initial state before the process was found about 44.9594 LMH but it reached after fouling to 17.2921 LMH.

(6) Chemical cleaning with simple acid as citric acid $C_6H_8O_7$ (0.15M), for M_C flux reached after chemical cleaning with citric acid to 24.20889 LMH, but M_L after chemical cleaning with citric acid reached to 31.125 LMH, also with cleaning with simple base as sodium hydroxide (0.1M), since for M_C flux reached after chemical cleaning with sodium hydroxide to 27.6673 LMH, but M_L after chemical cleaning with sodium hydroxide reached also to 27.6673 LMH.

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