Separation of hydrocarbons from refinery wastewater using polypropylene membrane (PP) with membrane distillation method

Jafar Hamid Zadeh[1,*], Prof. Muzafar Isabaev[2]

[1.] Department of Chemistry, Faculty of Basic Sciences, Islamic Azad University, Gorgan Branch, Gorgan, Iran
[2.] Department of Chemistry, Academi Sciences Tajikestan University, Dushanbe Branch, Dushanbe, Tajikestan
[*]**Corresponding author:** jafar.hamidzadeh@yahoo.com

Abstract: In chemical industries a huge portion of energy is employed for separation, concentration, and purification. As a result, significant works have been carried out in order to improve traditional processes and saving technologies in consuming energy. Because of complexity and high cost of current processes, membrane separation technology has been recently examined as a good alternative. Membrane distillation (MD) has been taken into consideration as a new membrane distillation process enables to separate particles as tiny and petite as 0.1-7nm. This process functions in low temperature between 30-90ºC that needs little source of energy besides high economic benefit. In membrane distillation (MD) process a hydrophobic membrane is utilized in contact with an input food solution. The base is on vapor-liquid equilibrium. In the present paper, alongside with membrane distillation (MD) the appropriate laboratory system will be examined additionally.
[Jafar Hamid Zadeh, Muzafar Isabaev. **Separation of hydrocarbons from refinery wastewater using polypropylene membrane (PP) with membrane distillation method.** *Researcher* 2014; 6(5):62-67]. (ISSN: 1553-9865). http://www.sciencepub.net/researcher. 10

Keywords: membrane distillation (MD), hydrophobic membrane, nanometer particles, vapor-liquid equilibrium

1. Introduction

Today's MD is known as a low cost and highly productive separation process which is a proper alternative for conventional distillation processes due to low selectivity and large operating cost. It is a kind of thermal driving force process discovered in 1960s.
For a fluid transmission in MD a porous hydrophobic membrane is applied. The used membrane in MD is made of polypropylene (PP) like material. It possesses features including thermal stability, high chemical resistance against heat and organic solvents to make membrane.

The membrane has pores with 0.2-0.3 μm diameter and porosity 70-80%. This process works in temperature between 30-90ºC. Since it is a low consuming energy process the extra energy from other processes as well as earth and solar energy could be used (1). The process of membrane separation due to proper flexibility and productivity has been greatly concerned (6).

2. Mechanism of Membrane Distillation

The MD process is standing on vapor-liquid equilibrium and penetration of hypobaric membrane. In this process, at first the liquid around warm food is evaporated then vapor passes through membrane and the penetrated vapor is condensated in the other side of membrane (8).

Input food contacts with the membrane in tempreture30-90ºC. Because of discrepancy between vapor pressure in either side of membrane resulting from temperature difference, the vapor penetration takes place from hydrophobic membrane (9). The MD process holds certain advantages including (3 and 4):
Lesser vapor, temperature and pressure volume rather normal distillation

The MD process suffers from following disadvantages as:
High primary cost
Minimizing productivity with time passage

3. Effective Parameters in Process of MD

3.1. Food Temperature

By increasing food temperature, according to Antoine's equation, partial vapor pressure enhances consequently and leads to maximization of diffusion flux (3and 4).

$$(1\ Logp^{sat} = A - \frac{B}{T + C}$$

Where

p^{sat} :vapor pressure (Pa)

T= temperature (k)

C, B, A= component-specific constants

3.2. Food Concentration

If the food contains volatile compounds, increased concentration of food makes diffusing flux raises (2 and 3) and if non-volatile compounds it has any increase causes decrease of diffusion flux (9 and 10).

3.3. Food Pace

As the food pace raises it makes heat transfer coefficient develops and thickness of the boundary layer reduces which in turn diffusion flux enhances (7).

4. Test system

In this system a 10Lit food container used.

To have better mixing and adjusting intensity of food flow, a bypass flow after pump outlet inside food tank is predicted. The rate of this flow back significantly influences on food temperature. Pressures were recorded by an aneroid sphygmomanometers.

The food was entered a membrane module to use intersection flow and enhances membrane turbulence. Food temperature also was measured by a mercury thermometer placed into the container. In order to control the food temperature more accurately a thermostat with maximum operating temperature 90ºC was installed.

Since food flow permanently rotates into the system, we presume that the food temperature throughout the system and on membrane surface is equals to the container temperature. The flow intensity was examined via timer method. Consequently, to perform the experiment a PP hydrophobic membrane applied.

The samples of flow from membrane were freezed till -30C then collected. The characteristics of used membrane are presented in Table (1).

Table 1: membrane characteristics of PP

Pore size (μm)	Porosity	thickness (μm)	material
0.2	75%	175-165	(PP) Polypropylene

In obtained wastewater the total amount of hydrocarbon either in the food or in the product was measured using Formacs device. Since the wastewater concentrations are fixed the experiments were carried out in three levels considering temperature, pressure, and flow intensity (pace of food) factors.

5. Method and Conditions

The experiments were performed through PP membrane and using …. and L90, Taguchi method of experimental design. In this design the experiment of three factors of temperature, pressure, and flow intensity in three different levels (9 different experiments) were assessed.

5.1. Temperature (T)

To test the effect of temperature on the system function the temperature was ranged between 25 to 75ºC. For doing prepared wastewater experiments temperature was adjusted at 35, 50 and 70ºC. According to path of flow back to the food tank and the food mixing it was impossible to lessen temperature less than 25ºC. and because of inconsistency in temperature and rapid decline at temperature higher than 80-90ºC as well as evaluating system productivity at average temperatures it was chosen to be 75ºC.

5.2. Pressure (p)

Evaluating the effect of pressure, other test factors related to wastewater were kept constant though the pressure was changing from 10 to 80 psi and 40, 60,and 80psi pressures were determined finally.

5.3. Intensity of flow (Q)

The experiments are different in 10-50ml/s food flow intensity which performed in three 20,30, and 40ml/s levels. In intensities lower than 15ml/s three was no chance of continuous flow and in higher than 50ml/s it leads to experimental failure.

Designing of performed experiments are presented in following table.

Table 2: planning experiments to perform on wastewater

Flow intensity (ml/s)	temperature (^{0}C)	pressure (psi)	Test no.
20	35	40	1
30	50	40	2
40	75	40	3
30	35	60	4
40	50	60	5
20	75	60	6
40	35	80	7
20	50	80	8
30	75	80	9

In prepared sample wastewater some hydrocarbons were found that contribute to decrease of surface tension of samples and consequently cause to pressure resistance fall in hydrophobic membrane. This in turn will make the food to pass from membrane in lesser pressure differences.

As a result of such impurities into the wastewater sample the vapor pressure decreases and the available

flux at 25C temperature and 80psi are insufficient for required analyzes. As experiments prolong transfer route of the product is blocked because of freezing. To improve the conditions, the low temperature 25ºC was maximized up to 35ºC.

6. Experiments results

In Table (3) the obtained results for performed experiments for the rate of flux and hydrocarbons are reported using PP membrane.

Table (3) shows the results for wastewater sample of membrane PP.

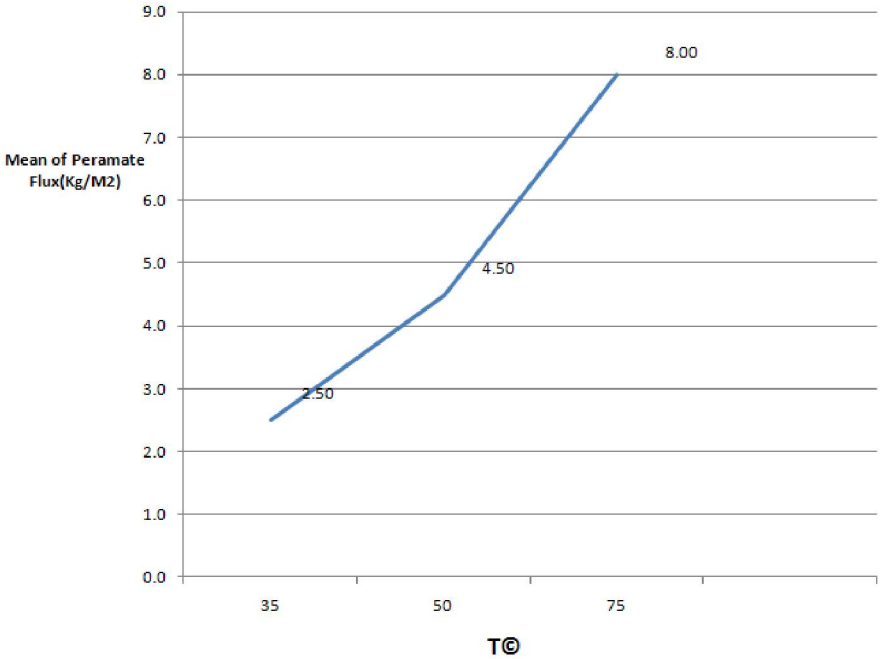
Table 3: results from sample wastewater obtained from PP membrane

hydrocarbon (mg/l)		Product flux (kg/m^{2}h)		Intensity of flow	Temperature	pressure	No.
Series2	series 1	series 2	series 1				
16.5	14.9	2.667	3.26	20	35	40	1
20.6	23.1	5.844	6.155	30	50	40	2
40.6	38	9.641	10.412	40	75	40	3
12.7	12.1	3.406	2.659	30	35	60	4
18.3	15.8	5.14	5.723	40	50	60	5
30.6	27.7	5.456	5.535	20	75	60	6
10	11.7	3.649	2.365	40	35	80	7
10.3	11.2	2.081	1.21	20	50	80	8
27.7	31.3	6.659	5.735	30	75	80	9

The product flux for membrane PP in time span 210min will decrease due to clogging of the membrane pores in a way that in 210min we experience the least product flux. According to diagrams in Fig. (2) Temperature puts the highest impact on the product flux related to vapor pressure behavior based on temperature.

$$SS = \sum_{i=1}^{K_A} \left(\frac{A_i}{n_{A_i}} \right)^2 - \frac{T^2}{N}$$

SS= sum of squares for each parameter
Ai= sum of observations in
level i factor
K_A: number of parameter A levels
T=sum of observations
N= number of observation
n_{Ai}= number of observation in level i factor A [Q]
P= percentage of each parameter portion



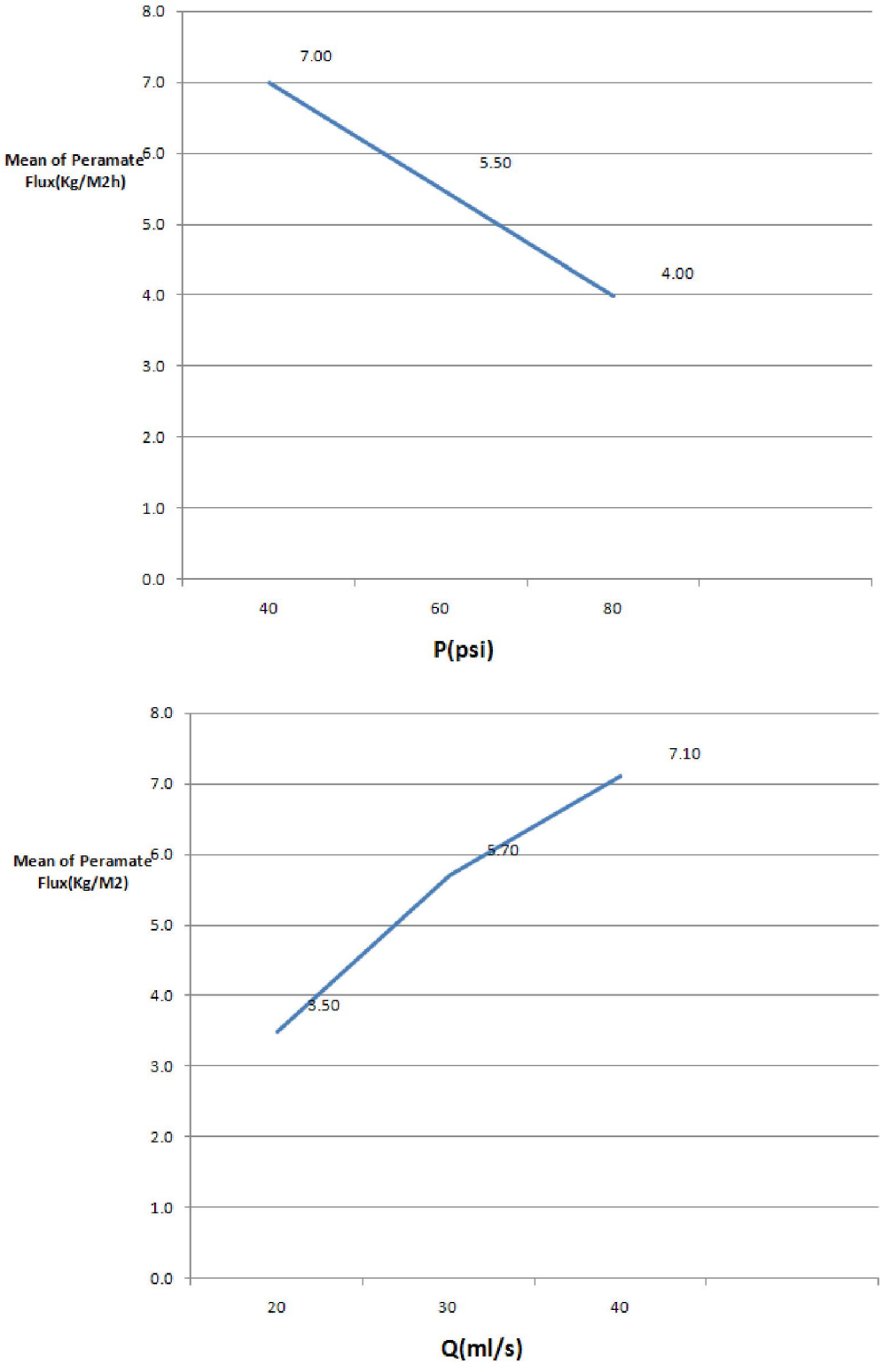
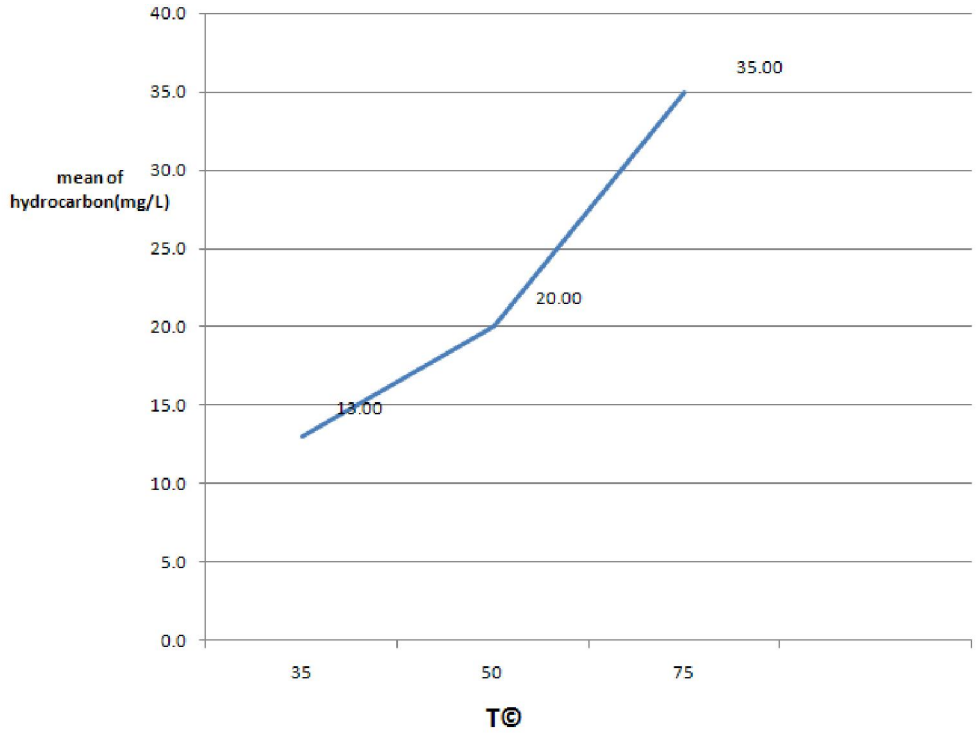
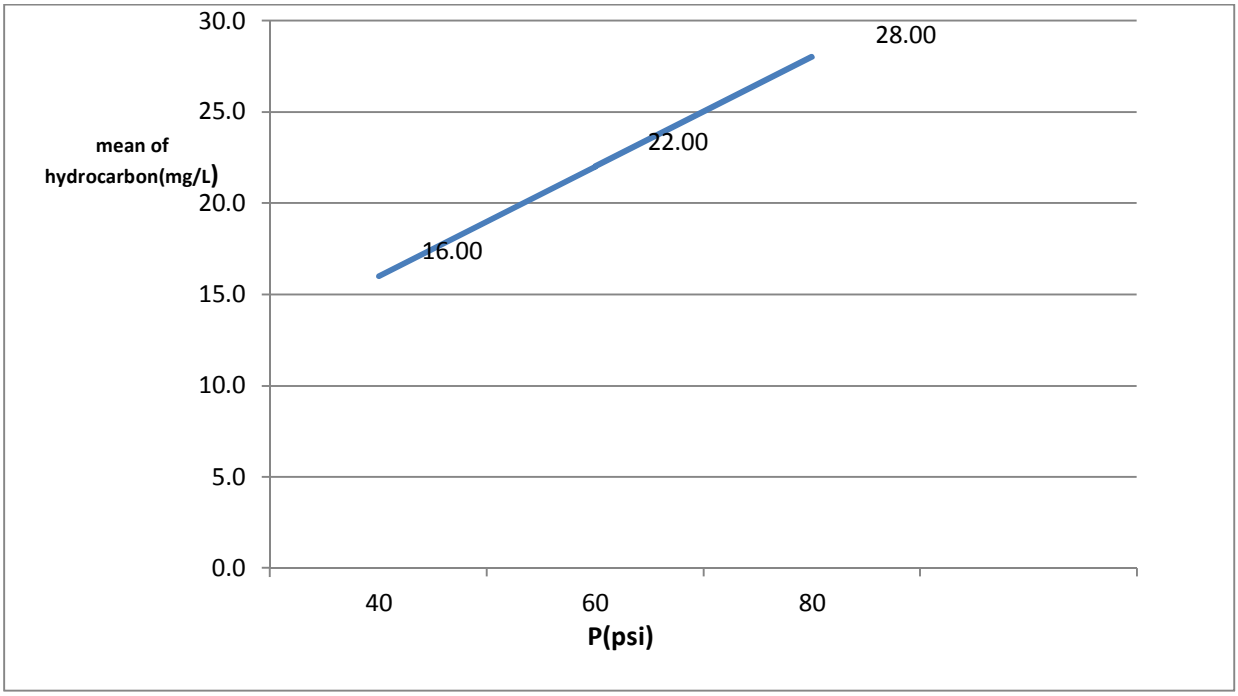


Figure 1: diagrams related to the effect of each factor on rate of mean of peramate flux using PP membrane According to diagrams in Fig.(1) it could be said that all three pressure, temperature and flow intensity influenced the rate of available hydrocarbon in the product. More their amount increase the rate of hydrocarbon enhances more. Also, based on the Table (4) it is possible to say that the temperature has the highest effect on level of hydrocarbon.

Table 4: obtained results for level of hydrocarbon

(%)P	SS	factor
15.18	210.19	pressure
85.28	1286.65	tempreture
2.69	402.23	Intensity of flow





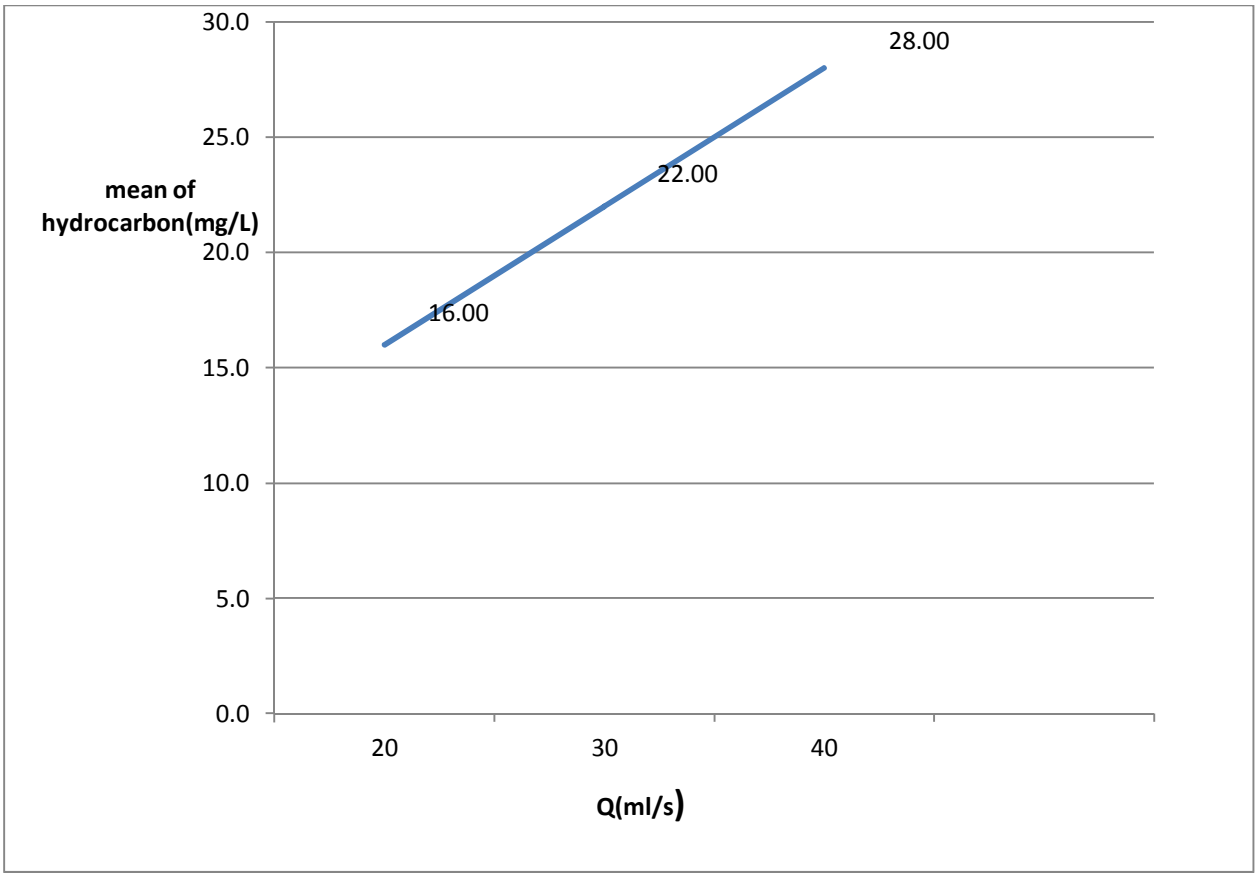


Figure 2: diagrams related to the effect of each factor on rate of hydrocarbon using PP membrane

7. conclusion

7.1: based on diagrams in Fig.(1) we can see that : through an increase in temperature, and flow intensity the product flux maximizes which the temperature puts the highest effect.

7.2: according to diagrams in Fig. (2) in membrane PP three T,P and Q are influential on product quality. The increase in T,P and Q leads to increase in level of hydrocarbon.

References

1. J. Wagner, "Membrane Filtration Hand book", 2nd Edition, Revision 2, osmonics, PTFE 8-15, 2001.
2. M. Cooke, C.poole, I.D. Wilson, "Encyclopedia of separation science, Academic press, PTFE. 459-567, 2000.
3. S.P. Nunes, K.V. Peinemann, "Membrane Technology in the chemical industried", wiley, PTFE. 134-139, 2001.
4. M. Cheryan, N. Rajagopalan, "Membrane Processing of oily stereams wastwater treatment and waste reduction." Journal of membrane science, volume 151, PTFE. 13-28, 1998.
5. Mohamad ali. Safari; "Water seporation from petrochemcal waste water by vocuum membrane distillation," 2008.
6. Jalal. BarzinT Majid Esmaili; " Membrane Fouling and Regeneration Methods "17 – 50(2005)
7. Barzin J. and Sadatnia b. (2007) " Theoretical phase diagram calculation and membrane morphology evalution for water/solvent/ polyethersulfone systems", polymer, 48,1620-1631
8. A.M. alklaibi, NoamLiar ; Transport analysis of air-gap membrane distillation"; Journal of membrane Science 255 (2005)
9. Phattaranawik J, Leiknes T, Pronk W, " Mass transfer studies in flat – sheet membrane contactor with ozonation ", Journal of Membrane Science, Volume 247,pp. 153-167,(2005)
10. Siavash Madaeni; " Membranes and Membrane Processes " 12-60 (2002).

3/30/2014