The Influence of Operation Conditions on the Permeative Flux of (PVC/PS) Hollow Fiber Membrane

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ABSTRACT

Membranes have gained an important place in chemical technology and are used in a wide range of applications. This investigation has studied the effect of operating conditions such as temperature, trans-membrane pressure and solute concentration on the separation performance of (PVC/ PS) hollow fiber membrane, which was prepared in the laboratory from 15% (PVC) and 2% (PS) using phase inversion method. An attempt was done to investigate the ability of PVC/PS hollow fiber membrane for ultrafiltration application. A (PVP) solute was used to measure (PVP) rejection of prepared membrane.

The predicted flux was found to increase from (18.88 $l/m^2.hr$) to 33.05 $l/m^2.hr$) when the operation temperature was increased from (10℃) to (30℃).While it increased from (28.57 $l/m^2.hr$) to (263.36 $l/m^2.hr$) when the operation pressure was increased from (1bar) to (3bar). It was also found to decrease from(17.97 $l/m^2.hr$) to (12.20 $l/m^2.hr$) with increase solute concentration from (1000ppm) to (2500ppm). The rejection efficiency was equal to (99.93%) when using (2500ppm) solute. This is considered within UF range.

Keywords: Ultrafiltration ; Membrane; PVC/PS hollow fiber .

تاثير ظروف الغشاء على الجريان التنافذي للغشاء الليفي المجوف (PVC/PS)

الخلاصة

الاغشية تكسب مكانة مهمة في تقنية الكيمياوية وتستعمل في مدى واسع من التطبيقات . يتضمن هذا البحث درسة تاثير الظروف التشغيلية مثل درجة الحرارة والضغط وتركيز المحلول على اداة عمل غشاء (PVC /PS) الليفي المجوف والذي تم تحضيرة في المختبر من (PVC) وبنسبة 15% و(PS) بنسبة 2% باستخدام طريقة الطور الانعكاسي .وايضا في هذا العمل تم دراسة قابليةاستعمال الغشاء الليفي المجوف في تطبيقات ال(UF) . تم استخدام PVP كمادة مذابة لغرض قياس كفاءة الارجاع لل (PVP) من قبل غشاء(PVC /PS) الليفي المجوف . لقد وجد ان نفاذية التدفق ازداد

من (18.88 L/m^2.hr) الى (32.75 L/m^2.hr) بزيادة درجة الحرارة من (10 °C) الى (30 °C) وكذلك ازداد نفاذية التدفق من (28.57 L/m^2.hr) الى (263. 36 L/m^2.hr) مع زيادة الضغط من (1 bar) الى (3 bar) ولكن نفاذية التدفق يقل من (17.54 L/m^2.hr) الى (12.20 L/m^2.hr) مع زيادة تركيز المذاب من (ppm1000) الى (25000 ppm) كفاءة الفصل تساوي (99.93%) باستخدام (2500ppm) وهذا يعتبر ضمن المدى التطبيقي لل(UF).

SYMBOLS

C = Local concentration of the solute in the film (ppm)
C_f = Solute concentration in the feed solution (ppm)
C_p = Solute concentration in permeate (ppm)
J_v = Volumetric flux of solution (L.m^{-2}.hr^{-1})
R= Solute rejection (%)
S = Surface area of hollow fiber membranes (m^2)
t= Time (hr)
T = Temperature (K)
V = Total volume of permeate (L)

INTRODUCTION

Ultrafiltration of macromolecular solution has become an increasing important separation process [1]. Ultrafiltration is applied in a wide variety of fields, from the chemical industry (such as electrocute paint recovery, latex processing, textile size recovery, separation of oil-water emulsion, pharmaceutical industries, metal processes industries, pulp and paper industries, leather processing industries, PVP (polyvinyl acetate) industries and food industry and water treatment, medical application such as kidney dialysis operations [2,3]. UF is the separation or concentration of a large molecular weight solute (1000 -100,000 dalton), which means, the smallest molecular weight species for which the membranes have more than 90% rejection. However, the pore size of an UF membranes range from (0.001 -0.1µm) [4]. Separation occurs by sieving mechanism.

Because this process is a pressure-driven membrane separation process, the pressure applied to the working fluid provides the driving potential to force the membrane. Typical driving pressure for UF systems are in the range of (70-700) Kpa [3]. There are there six basic UF module; spiral-wound, tubular, hollow-fiber, plate units, pleated-sheet cartridges and rotary modules [5]. Hollow fiber is one of the common ultrafiltration designs in which the membrane is formed on the inside of tiny polymer cylinders fabricated into a tube-and-shell arrangement. The advantages of this arrangement are low cost of investment and operation, easy flow control and cleaning , and a major advantage of hollow fiber membranes is that compact modules with very high membrane surface areas can be formed [1, 2].

Permeative flux is an important parameter in the membrane separation processes and affected by many factors such as trans-membrane pressure, feed temperature and concentration of feed solution [5]. The effects of operating conditions on the permeative flux for ultrafiltration of aqueous solution of PVP-360 in hollow-fiber membrane modules; have been investigated by Yeh and Wu [3]. Based on the resistance-in-series model coupled with the gel-polarization model under the consideration of the declination of trans-membrane pressure along the axial direction in the hollow fibers . Ali and Mohammad investigated the behavior of polysulfone amide (PSA) membrane in the presence of organic solvents (hexane) in edible oil processing by (UF) membrane. The result of this work show that the permeate flux decrease with time; this indicates a possible "interaction" between the solvent and the membrane material. Moreover, hexane flux found to be lower than water through UF membrane [6].

In the present study deals with the effect of solute concentration, feed temperature and trans-membrane pressure on the permeation flux of PVC/PS hollow fiber ultrafiltration membrane is one of the objectives of the present research.

EXPERIMENTAL WORK

The experimental apparatus in this work is shown in figure (2). The (PVC/PS) hollow fiber Membranes module fabricated in Chemical Engineering Department laboratories, University of Technology, it is consists of : 15% polyvinyl chloride (PVC) and 2% polystyrene (PS) using 83% Dimethylacetamide (DMAC) was used as a solvent in the preparation of the dope solution. The membrane specification are (tortusity = 0.175, inside diameter (ID) = 0.6 mm, outside diameter (OD) = 0.953mm, pore density = 77300 (pore/cm^2), pore size = 0.11 μm, porosity = 61% and L = 20 cm) the non-ionic solute poly vinyl pyrrolidone (PVP) with molecular weight (360000 Da) were supplied From (Fluka chemika Co). The tested polyvinyl pyrrolidone (PVP) K-90 non-ionic solute which more than 99% retained by the membrane .The solvent was distilled water.

Experimental Procedure Of Ultrafiltration System

PVP/PS hollow fiber membrane module was first prepared. Four fibers membrane were cut and put at both ends with epoxy resin in a stainless-steel module, and the effective length of the hollow fiber membrane which is 20 cm, was placed as effective length for permeation. To eliminate the residual glycerol present inside the membranes, each module was immersed in distilled water for (1 or 2) days, prior to pure water ultrafiltration tests. Pure water permeative flux (J_w) of hollow fiber membranes was obtained as follows [8]:

$$J_w = \frac{V}{t \times s} \qquad \text{……. (1)}$$

where J_w is the permeative flux of the UF membrane for distilled water (L/m^2.hr); t is the permeation collection time in (hr); V is the volume of permeation in liter; S is the membrane outer surface area (m^2) and S ($59.58\times 10^{-5} m^2$).

Measurement Of Permeative Flux And Solutes Rejection

The membranes permeate flux was measured with the following variables:

a. Solute concentration:

UF experimental system used for the separation performance was tested using of (PVP) solution. The permeability of hollow fiber ultrafiltration membranes were performed at a trans-membrane pressure of (1bar) and room temperature (25℃) with different PVP concentration in feed solution(i.e.1000-2500ppm). PVP solution was prepared from (1g) of (PVP) with (1 liter) of distilled water. The operation was done under trans-membrane pressure of (1 bar) and (25℃) with constant feed flow rate (500 cm^3/min). The permeation of the PVP solution was calculated using equation .The concentration of the solute was determined based on absorbance in UV-spectrophotometer solute (UV160) at specified wavelength (395-280 nm). The rejection of PVP/PS hollow fiber membranes was calculated using the following equation [5]:

$$R = (1 - \frac{C_p}{C_f}) \times 100 \qquad \ldots\ldots. (2)$$

Where C_p and C_f represent the solute concentration in the permeate and in the feed solution, respectively

b. Feed temperature Experiments have been worked with the same procedure in the case of.concentration variation mentioned in the first step**,** but in this case, the permeation flux was measured using different feed temperatures ($10℃ - 30℃$) under (1 bar) trans-membrane pressure and solution was distilled water. The temperature of distilled water the temperature control was done using water bath.

C. Trans-membrane pressure

In this case, the trans-membrane pressure was regulated to a required valve by gauge pressure fixed in the system, while the operation conditions still constant with the solution (i.e distilled water), the room temperature (i.e 25℃) and the flow rate (i.e 500 cm^3/min).

RESULTS AND DISCUSSION

Effect of Solute Concentration on the Permeative Flux of (PVC/PS) Hollow Fiber Membrane

Figure (2) shows behavior of pure water permeative flux with time at 25℃ and 1 bar trans-membrane pressure. It can be seen that the pure water permeate flux of PVC/PS hollow fiber membrane decreases with time from 79.37 to 69.76 (l /m^2.hr) and remains stable at this value.

Figure (3) shows the effect of PVP concentration in feeding solution on the permeative flux of PVC/PS hollow fiber membranes at 25℃ and 1 bar trans-membrane pressure. From this Figure it can be seen that the permeative flux decreases from 21.72 to 16.71(l/ m^2.hr) using 1000 ppm of PVP solution. With an increase of PVP concentration to 1500ppm in feed solution, the permeative flux decreases from 16.71 to 15.04 (l/m^2.hr), while the permeate flux of the PVC/PS hollow fiber membranes decreases from 13.37 to 11.69 (l/m^2.hr) for 2500ppm concentration of PVP feeding solution. It can be seen that the permeate flux is approximately constant at13.37 (l/ m^2.hr) for 2000 ppm of PVP solution. From above it can be said that with an increase of the solute concentration in feed solution the permeate flux of the hollow fiber membranes decreases.

This is attributed to the increase in the viscosity of the solution and this leads to build a layer on the outer surface of the membrane, which prevents or reduce the permeability of the solution through the pores of the hollow fiber membranes. This phenomenon is called the concentration polarization.At the beginning, the permeation of flux is high but it drops quickly and then decreases gradually. This behavior which is a typical trend shows membrane fouling during PVP processing [8].

Figure (4); illustrates the effect of different solute concentrations (PVP K-90) (i.e., Rejection% 1000, 1500, 2000 and 2500 ppm) on separation performance of (PVC/PS) hollow fiber membranes at room temperature and trans-membrane pressure (1bar). It can be seen that the (PVP K-90) rejection increases during 70 min and after that increases with increase in (PVP K-90) concentration in feeding solution from 1000 to 2500 ppm. Besides, it can be found that the separation performance of (PVC/PS)hollow fiber membranes using 1000 ppm as (PVP K-90) concentration in feed solution is higher than that using 1500 and 2000 ppm of (PVP k-90). In addition, from Figure (4) it can be found that the separation performance of the (PVC/PS) hollow fiber membranes is approximately constant during the run of the experiment using 2000 ppm. With increase in solute concentration in feeding solution, the concentration polarization becomes more serious and impressive because of the viscosity of the feed solution increases with solute concentration and the buildup solute on the membrane surface is high with solute concentration, all these make the solute back transport from the membrane surface to the bulk stream. Figure (5) shows the effect of different (PVP K-90) concentrations on the average permeative fluxes of (PVC/PS) hollow fiber membrane at room temperature and trans-membrane pressure (1bar).Increasing the (PVP K-90) concentration from 1000 to 2500 ppm, decreases the average permeative fluxes from 18.38 to 13.37 (l/ m^2.hr). Figure (6) shows the effect of trans-membrane pressure on the permeative flux with time of PVC/PS hollow fiber membranes. It is very clear this figure shows that increasing of the trans-membrane pressure from 1bar to 3 bar leads to increase the permeation of flux from 30 to 85.21 (l/m^2. hr) after 75 min of the experiment. One of curious aspects of Figure (6) is that flux does not increase monotonically with pressure; when the pressure is increased permeative flux, because of flux directly proportional to the pressure drop across the membrane as shown in Figure (7).

Effect Of Feed Temperature On The Permeation of Flux Of (Pvc/Ps) Hollow Fiber Membrane

Figure (8) shows effect of feeding temperature on the pure water permeation of flux of PVC/PS hollow fiber membranes. It can be seen that the pure water permeation flux decreases from 21.72 (l/m^2.hr) to 18.38 (l/m^2.hr) using feeding solution temperature at 10 °C, while the pure water permeation flux of the PVC/PS hollow fiber decreases from 21.72 (l/m^2.hr) to 20.05(l/m^2.hr) with increase in the feed temperature from 10 to 15°C. In addition, using 20, 25, and 30 °C as feed solution temperature the pure water permeation flux decreases from 23.39, 33.42, and 45.11 (l/m^2.hr) to 21.72, 27.57 and 30.07 (l/m^2.hr) respectively. It is worthy to mention here that the feed temperature has a strong effect on the permeation of flux as can be seen from the results above, where the pure water permeation of flux increases from 18.38 to30.07 (l/m^2.hr) with increase in the feeding temperature from 10 to 30 °C, it means that the increments in flux is around 66%.

The average pure water permeation flux increased from 18.94 (l/m^2.hr) to 33.05 (l/m^2.hr), hence the permeation of flux is affected strongly by increasing the solution temperature as shown in Figure (9). Thus, temperature is expected to have a rather important effect on the average permeative fluxes.

CONCLUSIONS

PVC/PS hollow fiber membrane composed of 15% PVC and 2% PS can be used for ultra filtration application. The separation performance of PVP solution using PVC /PS hollow fiber was in the range (97.5 % - 99.81%) and the efficiency of membrane decreases due to concentration polarization and fouling. The concentration polarization is increased with increasing feed concentration and decreasing with pressure and temperature.

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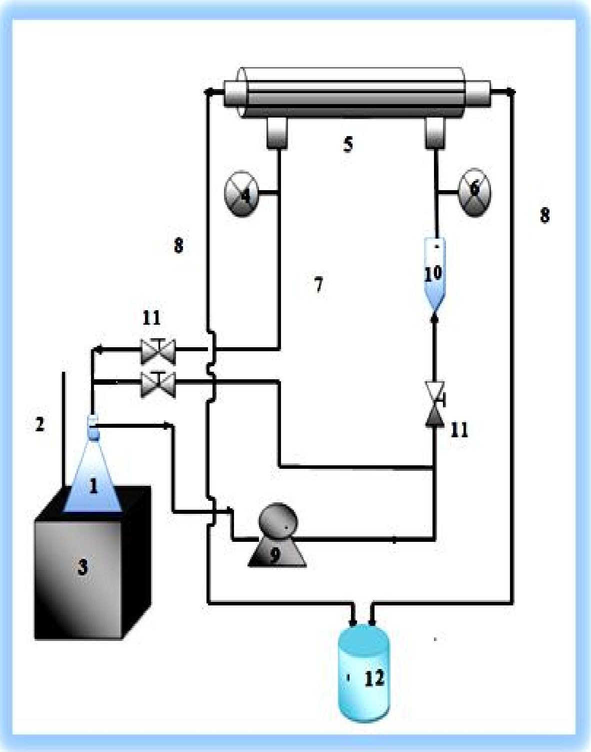

1. Conical flask of feed solution.
2. Calibrated thermocouple.
3. Water bath used to control temperature.
4. Outlet pressure gauge.
5. Membrane module (PVC/PS) hollow fiber.
6. Inlet pressure gauge.
7. Concentrate line.
8. Permeate line.
9. Pump
10. Rotameter
11. Valve used to regulate the flow rate.
12. Collector

Figure (1) Schematic diagram of UF experimental system.

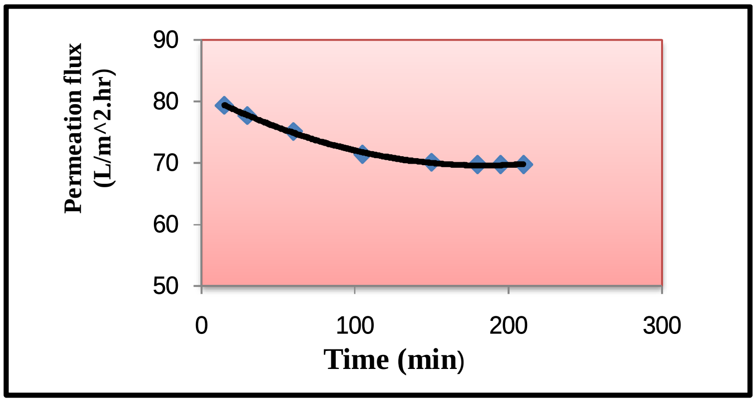

Figure (2) pure water permeation flux with time of PVC/PS hollow Fiber membrane at room temperature and 1 bar pressure.

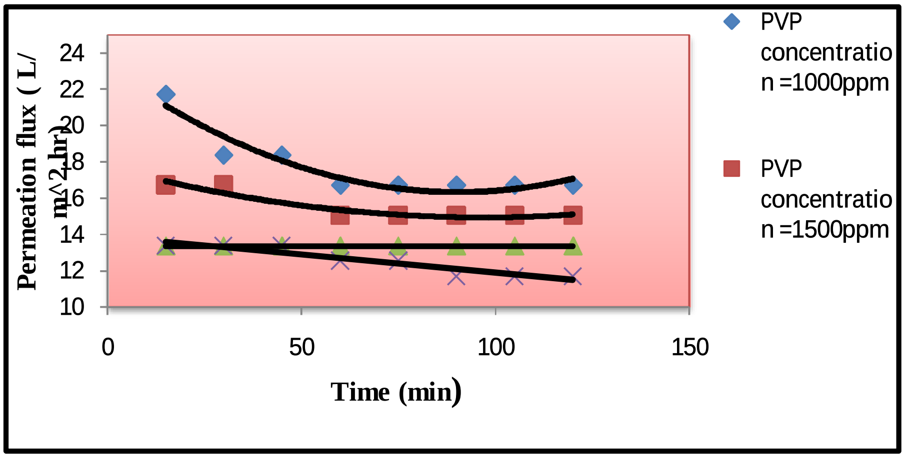

Figure (3) Effect of PVP concentration in feed solution on the permeation flux of (PVC/PS) fiber membrane at room Temperature and1bar pressure.

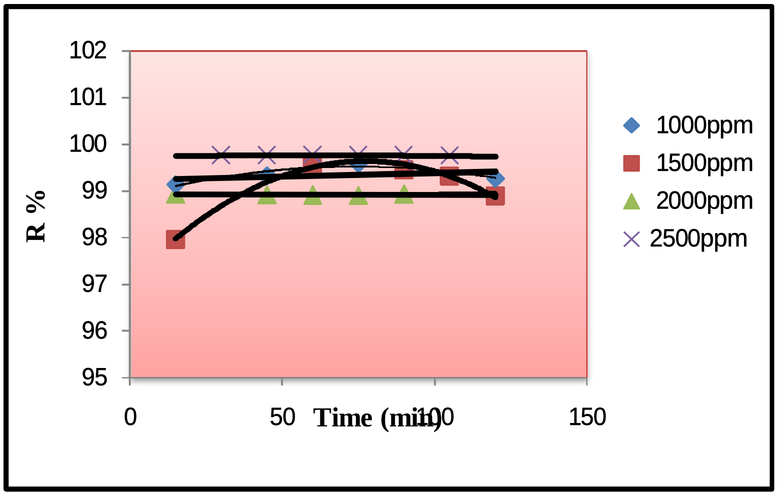

Figure (4) PVP rejections percentage with time of PVC/PS hollow fiber membrane as a function of (PVP K-90) concentration.

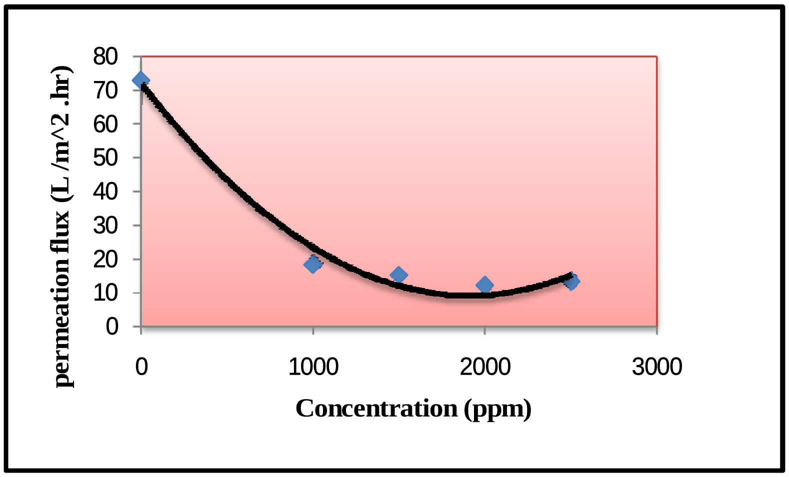

Figure (5) Effect of solute concentration on the membrane permeation flux.

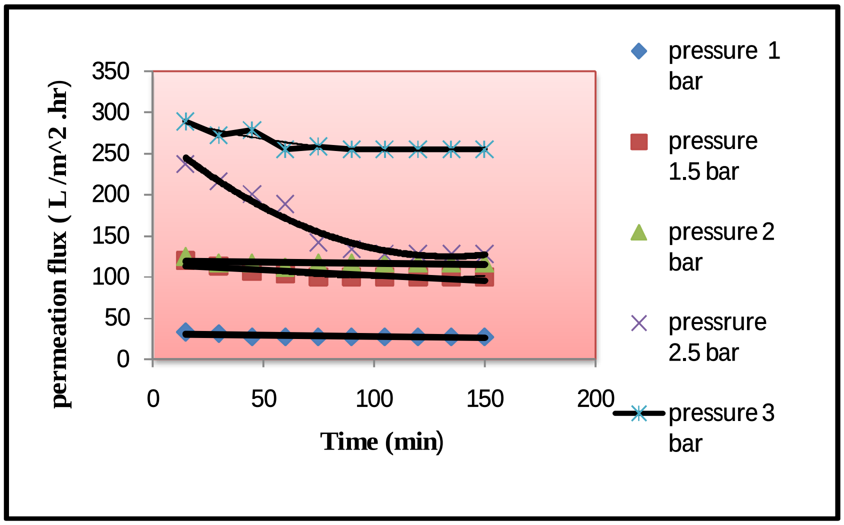

Figure (6) Effect of trans-membrane pressure on permeation flux o Membrane f PVC/Ps hollow fiber membrane with time.

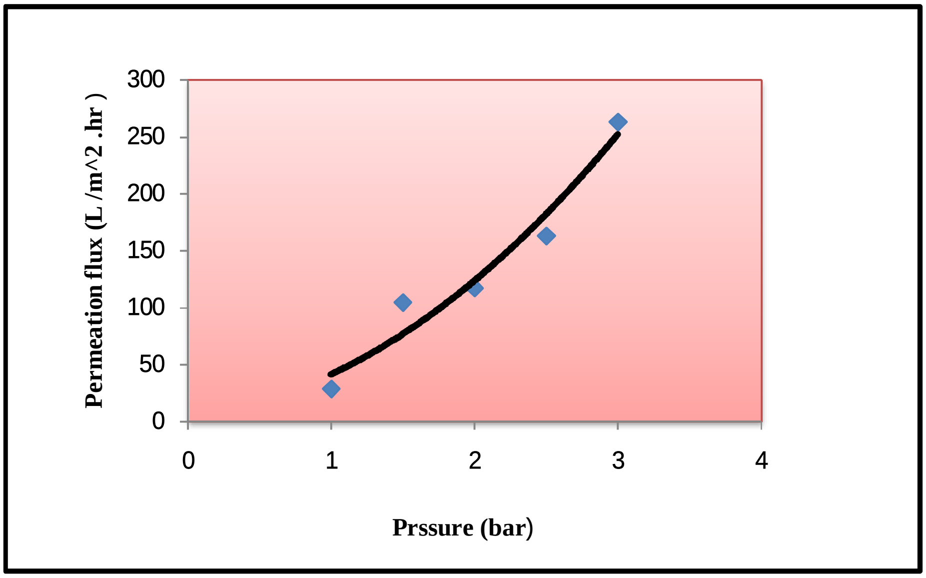

Figure (7) Effect of trans-membrane pressure on the average pure water permeationflux of the PVC/PS hollow fiber membrane.

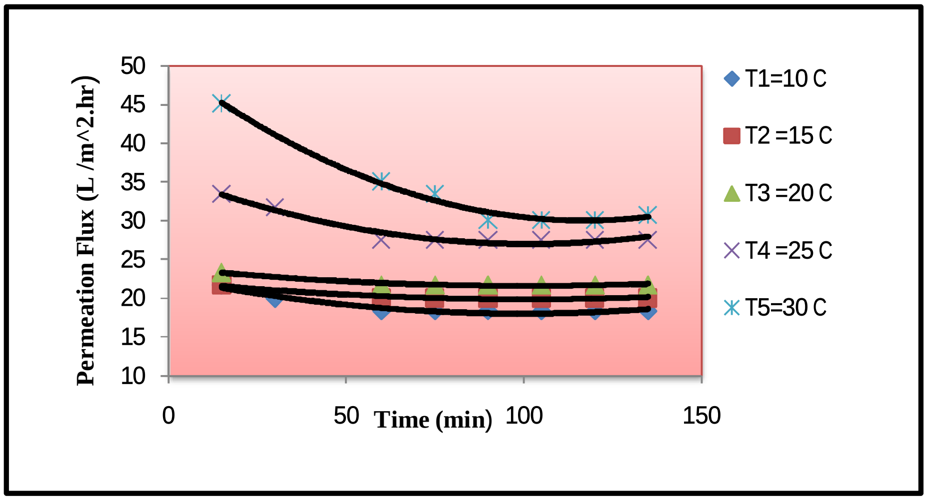

Figure (8) Effect of feed temperature on the permeation flux of the PVC/PS hollow fiber membrane.

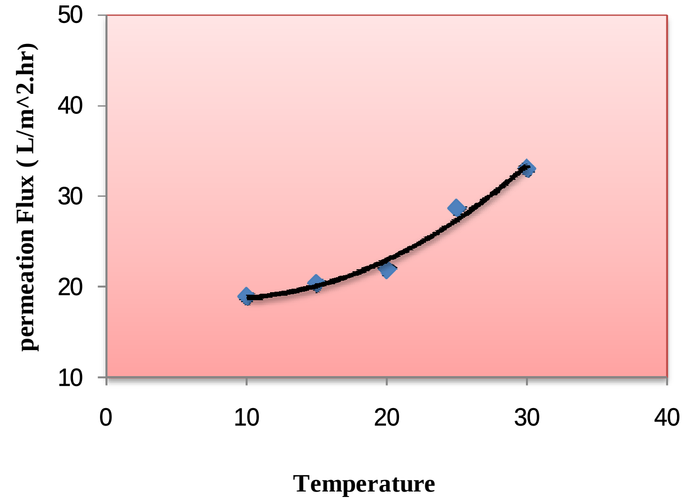

Figure (9) Effect of feed temperature on the average pure water Permeation flux of the PVC/PS hollow fiber membrane.