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Reverse Osmosis Polyamide Membrane for the Removal of Blue and Yellow Dye from Waste Water

Nada Mustafa H. AL – Nakib
Biochemical Engineering Department, AL-Khwarizmi College of Engineering _ University of Baghdad _ Iraq

Abstract
The present work aims to study the removal of dyes from wastewater by reverse osmosis process. Two dyes were used direct blue 6, and direct yellow. Experiments were performed with feed concentration (75 – 450 ppm), operation temperature (30 – 50 ^{o}C) and time (0.2 – 2.0 hr). The membrane used is thin film composite membrane (TFC). It was found that modal permeate concentration decreases with increasing feed concentration and time operating, while permeate concentration increases with increasing feed temperature. Also it was found that product rate increase with increasing temperature, but it decrease with increasing feed concentration and time. The concentration of reject solution showed an increase with increasing feed concentration of dyes and feed temperature, while decreases with increasing time operating of reverse osmosis unit. The maximum rejection for direct blue 6 and direct yellow are 98.89% and 98.30% respectively. The maximum recovery percentage for direct blue 6 and direct yellow are 17.84% and 18.20% respectively. The maximum concentration factor of direct blue 6 is 1.227 and for direct yellow is 1.272.

Keywords: reverse osmosis, Dyes (direct blue 6, direct yellow), Fouling, membranes

Introduction
Large amounts of dyes are used for various industrial applications; especially in the textile industries for dyeing cotton Petrinic [1]. The textile industry is characterized by using huge quantity of water. In fact the wastewater from textile dyeing industry is ranked the most polluting among all industrial sectors when considering both volume and composition and is classified is non-toxic although it contains a variable chemical composition of organic compounds such as synthetic dyes, surfactants, emulsifiers, cellulose and derivatives, starch, carbamide, nitrols and other organic substances Chokrabarti [2] and Manoskovn [3]. Dyes are mostly stable in light and heat. Also application of technologies which give more stability in the environment against sunlight, bleaches and oxidants, should be considered Gholami [4] and Bouy [5]. The classic and conventional treatment methods for these types of effluents are based on chemical precipitation, activated sludge, chloriation and adsorption of activated carbon and membrane process Allen [6] Albanis [7] and Mohamed [8]. In the recent years,

several factors have led to the development of membrane separation technology. Membrane process are often chosen in water treatment technology since these applications achieve high removals of constituents such as dissolved solids, organic carbon, inorganic ions. Membrane processes such as reverse osmosis (RO), microfiltration (MF), nanofiltration (NF) and ultrafiltration (UF) are used around the world for potable and ultra-pure water production, chemical process separations, as well as desalination of seawater. Microfiltration and ultrafiltration used as pretreatment for nanofiltration and reverse osmosis processes. Membrane separation processes are also used in food and diary industries, pharmaceutical and cosmetics production, water softening, ultra water production for electronic industries as well as treatment of municipal and industrial wastewater and agricultural drainage water. Reverse osmosis desalination has the advantage from the point of view of energy consumption, high product quality and flexible design and installation Cheryan [9].

The reverse osmosis membrane separation process called hyperfiltration because it will be noticed that reverse osmosis bears some resemblance to filtration, in that both involve removing a liquid from a mixture by passing it through a device that holds back other substance Ulrich [10]. It is a general and widely applicable technique for the separation, concentration or fractionation of substances in fluid solutions. It consists in letting the fluid mixture flow under pressure through an appropriate porous membrane, and with drawing the membrane permeated product generally at atmospheric pressure and surrounding temperature; the product is enriched in one or more constituents of the mixture, leaving a concentrated solution of other constituents on the upstream side of the membrane Sourirajan [11].

The choice of membrane material directly influences the separation efficiency. For obtaining a good efficiency, the membrane material must have high affinity for the solvent, and low affinity for the solute. The most common reverse osmosis membrane which attained the stage of economic application in water purification plants are made of cellulose acetate (CA) or polyamide (PA) Dan [12]. Membrane technology can reduce the volume, recover and recycle valuable component from the waste streams and /or remove recover the thermal energy in hot waste water Liv [13] and Koyuncu [14].

Reverse Osmosis performance can be expressed in terms of recovery and rejection:

1- **Recovery Factor (Y)** is defined as the fraction of the feed flow that passes through the membrane

$$Y = \frac{Qp}{Qf}*100 \qquad \ldots(1)$$

Where Q_p is the permeate volumetric flowrate ($m^3\ s^{-1}$) and Q_f is the fead stream flowrate, Hasan [15].

2- **Rejection Percentage (R)** defined as the extent to which a solute is rejected by the membrane

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

Where C_p is the permeate concentration [kg/m^3] and C_f is the feed stream concentration [15].

3- **Concentration Factor:** The concentration factor (CF) is the ratio of concentration of solute (dissolved species) in the concentrate or reject stream to its concentration in the feed stream

$$CF = \frac{\text{C concentrate}}{\text{C feed}} = \frac{\text{Cret}}{\text{Cf}} \qquad \text{...(3)}$$

4- Permeate Flux: The volumetric rate of flow through unit membrane.

$$J = \frac{v}{s.t} \qquad \text{...(4)}$$

Where S is area of membrane, v is volume of permeate and t is time, Hasan [15].

Experimental Materials

Two types of dyes were selected:

1. Direct yellow
2. Direct blue 6

Characteristics of these dyes are presented in Table (1). Solution of dyes (1000 ppm) were prepared by dissolving 1 g of each dye in 1 litter of distilled water and then diluted with distilled water to the required concentration 450, 350, 250, 150, 75 ppm

Table 1, chemical formula and wavelength at extinction measurement of the dyes examined

Dyes	Wave length (nm)	Structure	Mw
Direct yellow	430	$C_{30}\ H_{26}N_4N_{a208}S_2$	680.66
Direct blue 6	900	$C_{32}\ H_{20}N_6N_{a4}0_{14}S_4$	932.75

Experimental Procedure

Reverse osmosis system was installed in the University of Baghdad – the chemical engineering department lab. It consists of a vessel for wastewater with dyes which is prepared by adding dyes to distilled water; also there is a micro filter which is used to remove suspended materials, if existed, which is considered as a protector for the reverse osmosis membranes. After the feed water is fed into the micro filter as pretreatment then introduced to the RO membrane which is a spiral-wound module. High pressure pump (maximum pressure 120 psi) used to allow water pass through the thin film composite (TFC) membrane then into the product solution as shown in figure (1). This system is based on the concentration of dye solution as recycled back to the feed vessel to get the highest recovery percentage.

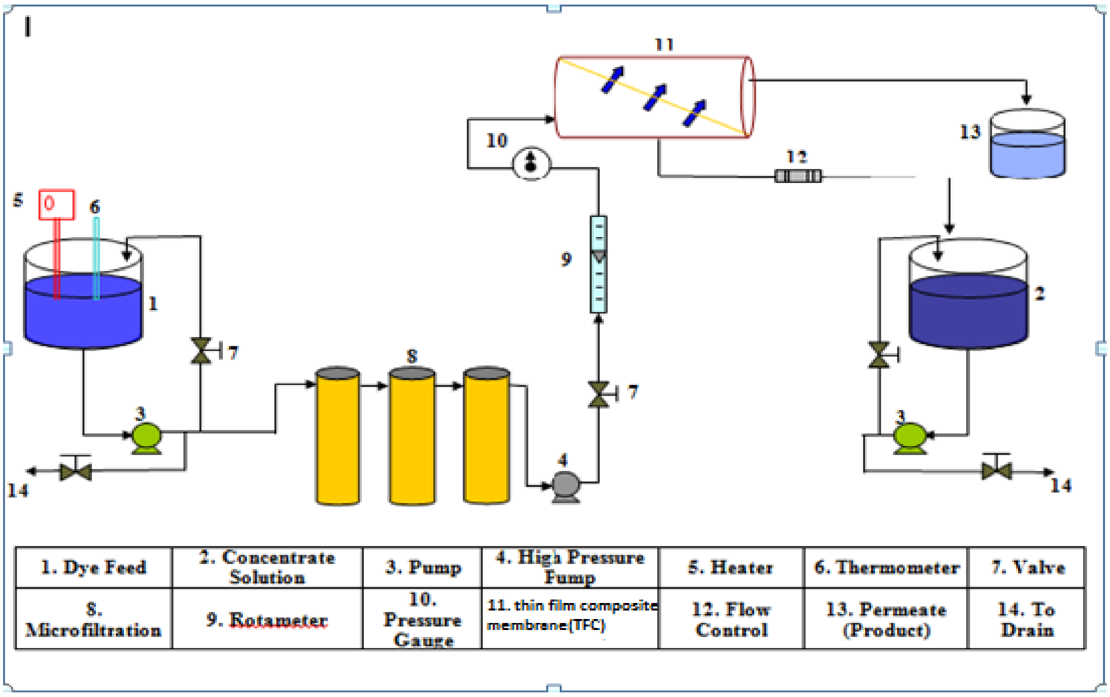

Fig. 1, Reverse Osmosis Process

Spectrophotometer with suitable wave length for each dye as shown in table (1) was used to measure the product solution, feed solution and reject dye solution every 15minutes. All experiments were carried out in 2hours to reach steady state conditions.

Water flux was calculated by dividing the permeate volumes by the membrane area and time (equation 4). At the end of the experiment solution was drained out and the system was washed by distilled water.

Result and Discussion

Effect of Feed Concentration

By increasing dye feed concentration, this appears as a decrease of water flux through the membrane as shown in Figure 2. As the feed concentration increased the product rate decreased. According to the Equation 1, recovery is a function of product rate. The increase of product rate will increase the recovery for all parameters studied in the present work and vice versa.

Figure 3 shows the effect of feed concentration on permeate concentration and reject percentage for blue and yellow dyes respectively. The figure indicate that the permeate concentration increasing when the feed concentration increased. The decrease of permeate concentration will increase the rejection percentage and vice versa (Equation 2). The possibility of fouling inside the pores of membrane would be larger in case of the concentrated solution flowing. This fouling could be acting in two ways. First blockage a number of pore completely or partly, so the flow would be decreased, and the second decrease the voidage and that also would be decreased the product rate. As shown in Figure 4 the effect of dye feed concentration on concentration of reject and concentration factor, the dye concentrations increases, the reject concentration (or concentrate) will increase. The increasing of reject concentration will increase the concentration factor (Equation 3).

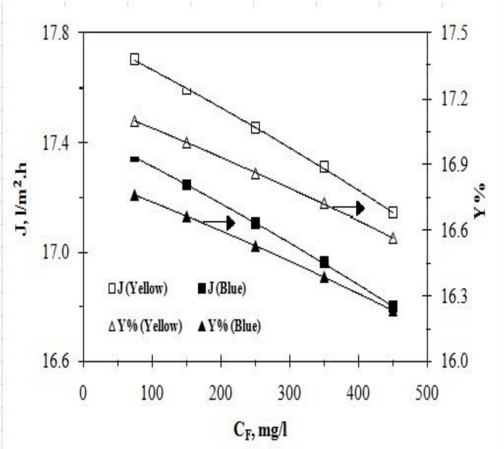

Fig. 2, Effect of feed concentration on permeate flow (J) and recovery factor (Y %)

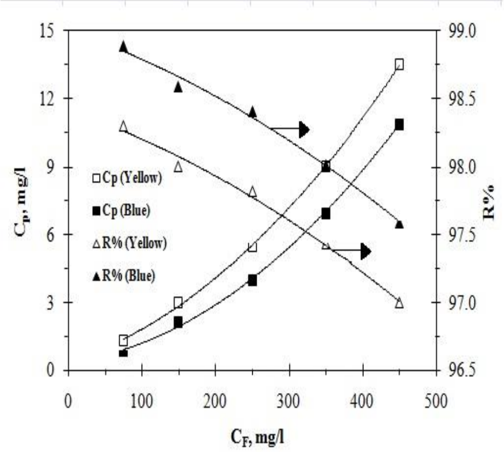

Fig. 3, Effect of feed concentration on permeate concentration (Cp) and rejection percentage (R %)

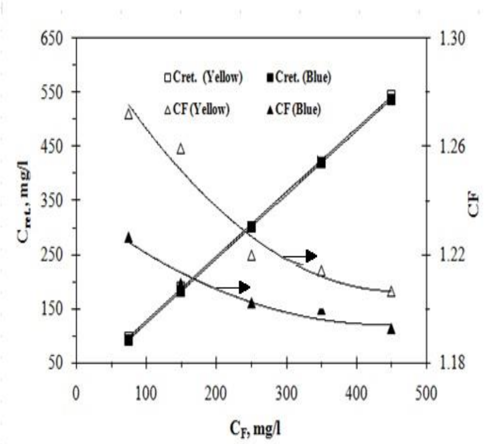

Fig. 4, Effect of feed concentration on reject concentration ($C_{ret.}$) and concentration factor (CF)

Effect of Operation Temperature

The inlet temperature effect on the product rate, increasing temperature will increase the permeate flux and recovery percentage as shown in Figure 5. A change in operating temperature will change (i) the densities and viscosities of solutions which increase the relative flow of the pure water through the membrane, (ii) by increasing operating temperature, solute (dye) flux increase, this appears as an increase of solute concentration in the product, and the decreasing of rejection percentage. This is shown in Figure 6. The concentrate behavior is shown in Figure 7 as a variation of reject concentration and concentration factor increases with increasing temperature. The increasing of temperature means the decreasing of the reject flow rate, which led to an increase in the reject concentration.

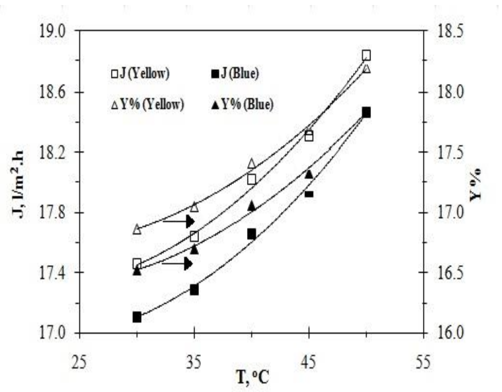

Fig. 5, Effect of operating temperature on permeate flow (J) and recovery factor (Y %)

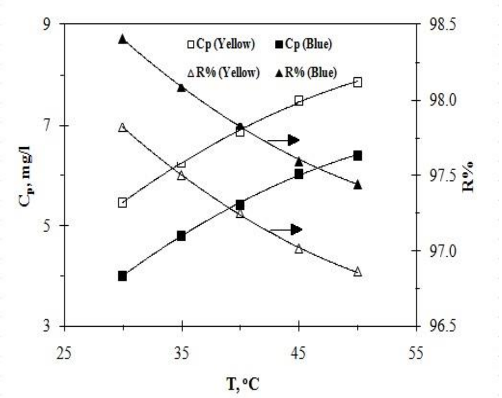

Fig. 6, Effect of operating temperature on permeate concentration (Cp) and rejection percentage (R %)

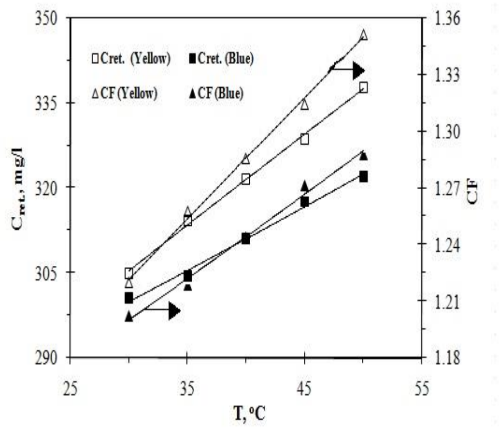

Fig. 7, Effect of operating temperature on reject concentration ($C_{ret.}$) and concentration factor (CF)

Effect of Operating Time

The flow rate from reverse osmosis unit decreases with increase in operating time. The product rate of a reverse osmosis system decrease as fouling occurs, because the foulants on the membrane surface retard the back diffusion of the dye into the bulk solution to cause concentration polarization at the membrane surface.

The increase in concentration polarization causes a decrease in the product rate that explain the decreasing of product rate with increase operating time As shown in Figure 8. The water recovery and permeate flux decrease with increasing operating time according to equations 1 and 4. Figure 9 shows the influence of operating time on rejection percentage. The increases in time cause an increase in fouling of membrane. This reason can be explain the increase dye concentration with increase in operating time which causes the decrease in rejection percentage.

Figure 10 shows the effect of operating time on concentration of reject and concentration factor for reverse osmosis unit. During the operation, water flux through the membrane decreases, for this reason the concentration of reject solution decrease. So, the reject concentration decreases with time increase. Concentration factor decreases according to Equation 3.

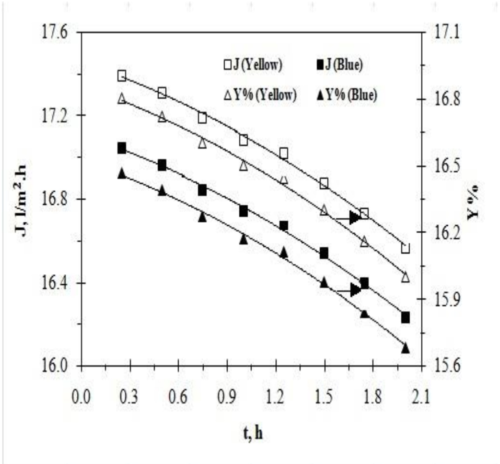

Fig. 8, Effect of operating time on permeate flow (J) and recovery factor (Y %)

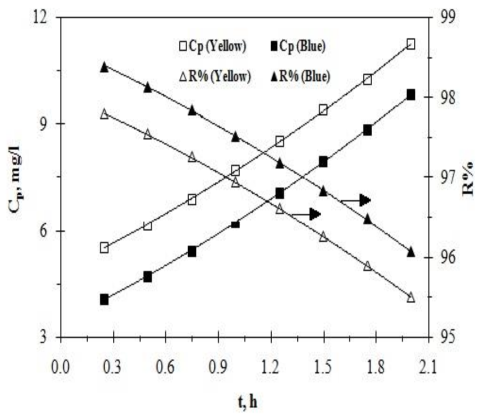

Fig. 9, Effect of operation time on permeate concentration (Cp) and rejection percentage (R %)

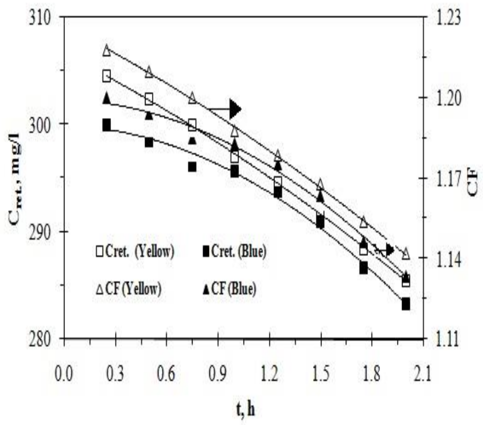

Fig. 10, effect of operating time on reject concentration ($C_{ret.}$) and concentration factor (CF)

Conclusion:

- Reverse osmosis gives a high efficiency in separation dyes. The product rate in RO increases with increasing temperature, but it decreases with increasing feed concentration and operating time.
- The increase in operating time, feed concentration and feed temperature will decrease the rejection percentage. The increase in feed concentration and operating time decrease concentration factor while increases in temperature increase it.
- The maximum recovery of dye (direct yellow) is 18.32% and for direct blue 6 is 17.84%. The maximum rejection of dye (direct yellow) is 98.30% and for direct yellow) is 98.30% and for direct blue 6) is 98.89%. The maximum concentration factor of direct blue 6 is 1.227 and for Direct yellow is 1.272.

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