Removal of Acid Blue Dye from Industrial Wastewater by using Reverse Osmosis Technology

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Abstract

This study is devoted to assess the removal of acid blue dye from simulated industrial wastewater by using integrated membrane system of microfiltration to remove the suspended solid followed by reverse osmosis filter (RO). The dye is currently used in Al-Kut textile factory, Wassit Governorate, Iraq. The effect of RO systems on percentage removal of dye and permeate flux were studied under different operating conditions, such as applied pressure (5-10 bar), initial dye concentration (25-100 mg/l) to satisfy the concentration in mentioned factory , at constant pH and room temperature.

The results showed that the removal effcienciey were increase with increasing the pressure up to (98%) and the initial concentration of the acid blue dye during 90 min of the operation. While, the permeate flux increases with increasing pressure, Also, the permeate flux was inversely proportional to the dye concentration in the system.

The total dissolved solids (TDS) was removed with high efficiency reaching nearly 100% by using RO membrane.

1.Introduction

The potential scarcity of water supplies on earth has become one of the most challenging problems of human beings. The world population is ever increasing, creating the need for more production of goods, leading to more industrialization, and hence more water consumption through the industrial processes. Today, approximately half of the available water is being used for domestic "purposes, and the other half is consumed by the industrial and agricultural activities [20]. In addition to fresh water shortage, industrial activities lead to the most severe environmental pollution problems via discharge of wastewaters into the receiving water bodies. Although treatment of these wastewaters before discharging is obligatory by the relevant environmental protection legislations. As a result, the water quality in the receiving environments rapidly deteriorates. The shortage of water supplies also forces the industrialists to pay even more for their fresh water consumption and wastewater generation. All these facts force the industrialists to consider the recovery and reuse of their wastewaters, at least to a certain extent [14].

Textile industry is one of the oldest and heaviest polluters in the world. Textile effluents have been subjected to a considerable extent of research for many years due to the fact that they are generated in huge volumes in addition to being quite complex in nature due to the presence of several dyes and auxiliary chemicals. The textile industry consists of a number of processes employed for converting fibers of natural origin such as cotton, silk and wool, and of synthetic origin such as nylon; first into fabrics by weaving and knitting and then into the final products by applying wet processes such as dyeing, sizing, printing, and finishing. These stages involve treating the fabric with chemical baths including dispersing agents, salts, emulsifiers, leveling agents, and in some cases heavy metals, and often require additional washing, rinsing, and drying steps, and hence they imply a large consumption of fresh water, energy, chemicals and a large production of waste streams. In terms of waste generation and environmental impacts, wet processing is the most significant textile operation. [14].

Dyes are aromatic organic compounds, and based fundamentally on the structure of benzene, toluene or naphthalene as they are typically derived from coal tar and petroleum-based intermediates. Through chemical processes such as nitration and sulfonation, these chemicals are processed into dye intermediates such as aniline, which are processed further by special operations like diazotization to give the final product - a dry chemical powder. There are many types of dyes, which are most commonly classified according to their structure or their dyeing properties. According to the dyeing properties the dye classes are; acid, basic, direct, disperse, mordant, reactive, sulfur and vat dyes. Each dye class is suitable to a specific type of fiber and hence the fixation rate of each class of dye is different. The highest and lowest fixation rates belong to basic dyes (97-98%) and sulfur dyes (60-70%), respectively [22]. In general, approximately 20-40% of the input dye remains in the wastewater [23]. Their concentrations in dye-baths range from 10 to 1000 mg/l [20]. The inefficiency of the conventional biological treatment methods for decolorizing the textile effluents leads to the discharge of highly colored wastewaters into the receiving environment. Accumulation of dyes in certain forms of aquatic life is suspected of leading to toxic and carcinogenic degradation products. Moreover, dyes limit aquatic plant growth by reducing light transmittance, and prohibiting the photosynthetic activity in" the receiving water bodies [5].

2. Membrane System

The experiments were preformed with a pilot plant as shown in **Fig. 1**. with recycling of permeate. The system is composed of two hollw fiber microfilters and RO cell were used simultaneously, feed tank, two typs of pumps (low perrsue for the feed water located after the feed tank and high pressure pump located before the membrane cell), four pressure gages , valves, and two flow meters ranges (2 to 150) l/min . The dimention of the system is (80 cm × 60 cm × 190 cm)

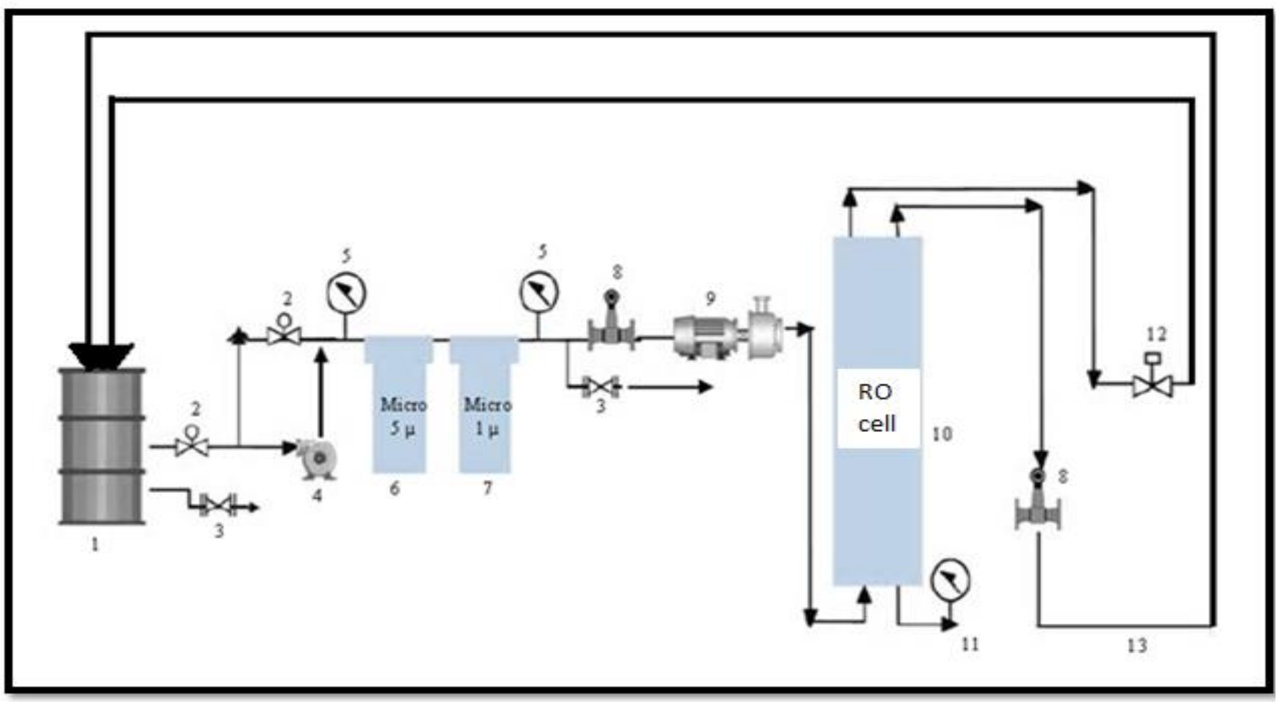

Fig. 1. Schematic diagram of the pilot plant.
(1. Wastwater Tank, 2.By bass valve, 3.Outer valve, 4.Low Pressure Pump, 5.Pressure Gauges, 6,7-MicroFilters (5,1 micrometer), 8. Flow meters, 9-High presure pump, 10-Housing for RO Membrane, 11. Pressure Gauges, 12-Out let valve 13-Permate valve)

3. Materials and Method

3.1 Dye

Acidic dye in blue color, blue is highest usage rates in Al-Kut textile factory was used. This dye was supplied from Al-Kut textile factory / Ministry of Industry .

3.2 Auxiliary Chemicals

Chemicals used to adjust the pH and to obtain the concentrations of the salts required for the study are 1- sodium chlorids with (Mwt 58 .44, purrity 99%, and purrity 40%, from BDH- England); 3-NaOH with (Mwt 39, purrity 99.9%, and from Merk- Germany); 4- $H_2SO_4$with (Mwt 98, purrity 99.9%, and from BDH- England).

3.3 Membrane

One type of membrane, (RO membrane was used. This membrane inserted into a stainless steel housing. The characteristics of RO membrane listed in Table 1.

Table 1. Characteristics of RO Membranes (supplyer company).

Type of membrane	RO
Model	ESPA1-4040
Material	Composite polyamide
Module	Spiral wound
Size(I.D, Length)(inch)	inch(4×40)
Active Area (m^2)	7.9
Max operating temp (℃)	45
Max Applied press (bar)	41.4
Manufacture	Hydranautics
Feed water pH Range	2-10
Surface charge (mV)	-5

3.4 Experimental Procedure

1. Dye solutions were prepared in four concentrations of ; 5 , 25, 50 , and 100 mg/l to study the effect of concentration on the dye removal. It was performed by mixing individual dye powder with tap water in the feed tank.
2. Supply different pressures; 5, 7.5, 9 and 10 bars, for each concentration of dye, to study the effect of dye pressure on the dye removal.
3. Prepare dye-salt mixture solutions, with added pure sodium chloride to tap water cotain dye . The TDS concentrations are; 600, 2000, 3000 mg/l, to study the effect of the TDS removal with time .
4. Supply different pressures; 5, 7.5 , and 10 bars. with the constant concentration of (TDS and dye) , to study the relation between the pressure and the permeate flux .
5. Prepared different cocentrations of the dye 25, 50, and 100 mg/l. with constant prssure , to study the relation between of dye consentration and permeate flux.

4. Sample analysis

All samples were collected and analyzed in labrotary of Al-Kut textile factory by standard methods. Shimadzu spectrophotometer UV-VIS ectrophotometer model (UB-1201 PC) was used to massured the colore at dominate wavelenth. TDS was measured by TDS meter from hanna-USA. Solution conductivity measured by conductivity meter (Horiba DF-H). Horiba pH meter are used to measured pH. "Retention factor (R) of each species is calculated by equation (1), [8].

$$R = \left(1 - \frac{C_P}{C_f}\right) * 100 \qquad .... \ (1)$$

Where R is retention factor (%) , C_P is concentration in the permeate (mg/L) , C_f is feed concentration (mg/L).

Flux is calculated by using equation (2) [7] .

$$J = \frac{Q_p}{A_s} \ ... ... (2)$$

Where

J: permeate flux ($l/m^2.h.bar$).
Q_p: permeate flow rate (l/hr).
A_s: membrane surface (activ) area" (m^2).

5. Results and Discussion

5.1 Effect of Dye Concentration on the Removal Efficienncy

Fig. 2, represents the percentage removal efficienncy of acid blue dyes at different concentrations (25, 50, 75 and 100 mg/l) using RO membrane at constant pressure 10 bar and pH 7. The removal percentage of acidic blue dye reachs 99% It can be noted that with increasing the dye concentration, the removal efficienncy was increased for acid blue, As the feed concentration changes the viscosity, density and diffusivity of the feed solution will change that may be affect on the removal efficiency. This result agrees with [17].

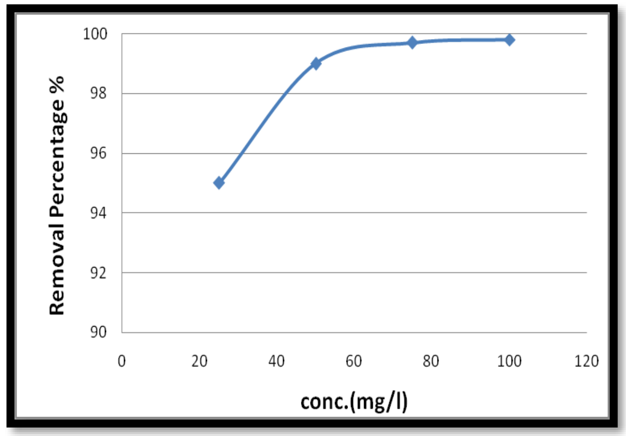

Fig. 2. Removal Percentage of Blue dye at different blue dye concentration using RO membrane at (P=10 bar, pH=7)

5.2 Effect of Pressure on Dye Removal Efficiency

Fig. 3 shows the effect of pressure on dye removal for blue acidic dye, at 50 mg/l dye concentration. Removal efficiency increases with increasing pressure; It means that with increasing operating pressure the dynamic force will improve and reduces the resistance through the membrane and control the boundry layer thickness, leading to membrane compaction. In Fig. 3 the removal efficiency reaches 99.8 % at 10 bars.

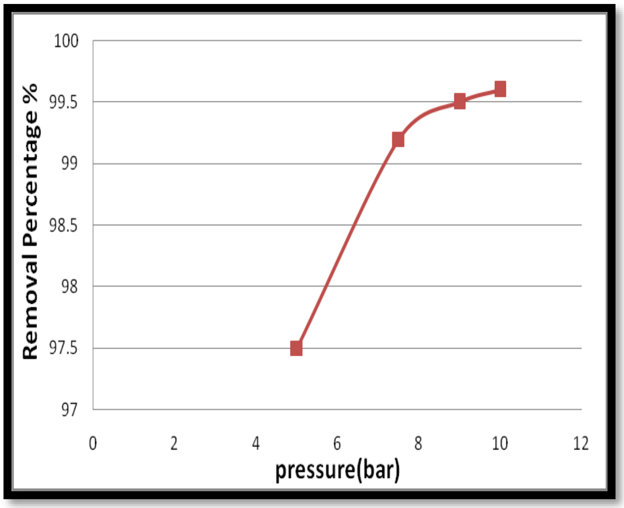

Fig. 3. The relation between pressure and dye removal (dye concentration = 50 mg /l , blue dye, RO)

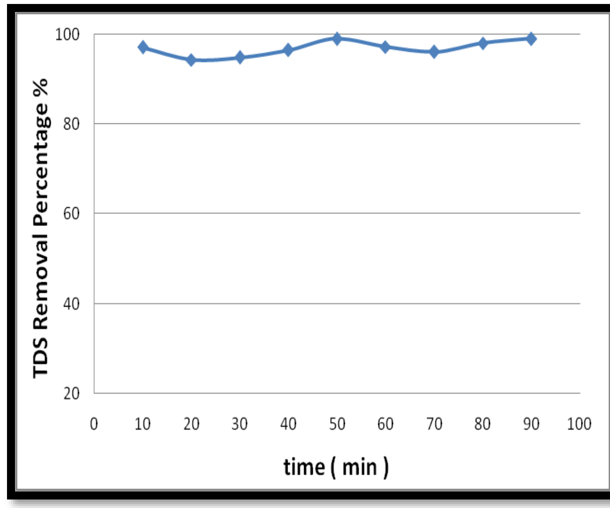

Fig. 4. TDS percent removal percentage with time for the wastewater cotaminated with blue dye using RO membrane

5.3 TDS removal

Fig. 4 shows the TDS percent removal with time for acid blue dye. TDS concentration 3000 mg/l and the concentration of dye was fixed at 50 mg/l under a constant pressure of 10 bars. All the experiments were carried out for 90 min to reach steady state conditions. The RO membranes is active in removing the salt from the wastewater. The reomval efficiency reaches up to 99.7 % for mix dye-salt solution.

5.4 Effect of Dye Concentration on Permeate Flux

Fig.s (5, 6, and 7) represent the relationship between permeate flux and time for acid blue dye at different dye concentratios and operating pressure**. Fig. (5)** shows the effects of blue dye on the permeate flux with time at opering pressure equals to 5 bar. At dye concentation of 25, 50 and 100 mg/l, the fluxe range between 23.3 to 10.6 (l/ m^2.h) at concentration 25 mg/l. While at 50 mg/l fluxe range between 20 to 11.7 (l/ m2.h). Finally for 100 mg/l the fluxe between 16.4 - 11.4 (l/ m^2.h) for the acide blue dye. All these testes achieved at the same TDS concentration (3000 mg /l).

Permeate flux was decreased with increasing dye concentration because of increasing the osmotic pressure and cocentrarion polarization at the surface of the membrane [1, 2, 18]

Also when the cocentration of the feed solution reaches the concentration of the solute at the membrane surface or gel layer, there will be no longer a concentration gradient in the boundry layer and, thus, no back transport of solute, resulting in zero flux . Membrane fouling occurs by adsorption of the dye onto the surface of the membrane at the experimental peroid [18]. **Fig. (6)** and **Fig. (7)** show the same results under 7.5 and 10 bars operating pressure respectivly.

Fig. (8) shows the relationship between concentration and the flux for the blue acid, reactive and dispers dyes at different oprating pressure and the TDS is 3000 mg/l. it can be noted that the fluxes decrease about linerlay with increasing the concentrations at the same pressure, due to the accumulation of solute onto membrane surface and that lead to increasing the polarization layer and decrease fluxes.

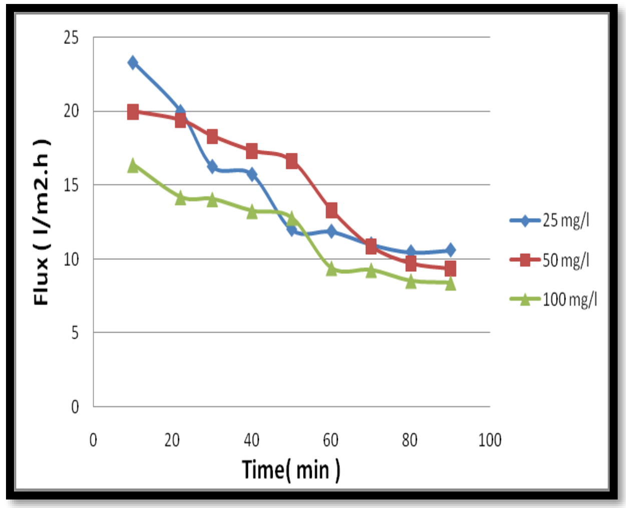

Fig. 5. Permeates flux with time for the Blue dye at the different concentration(P=5 bar)

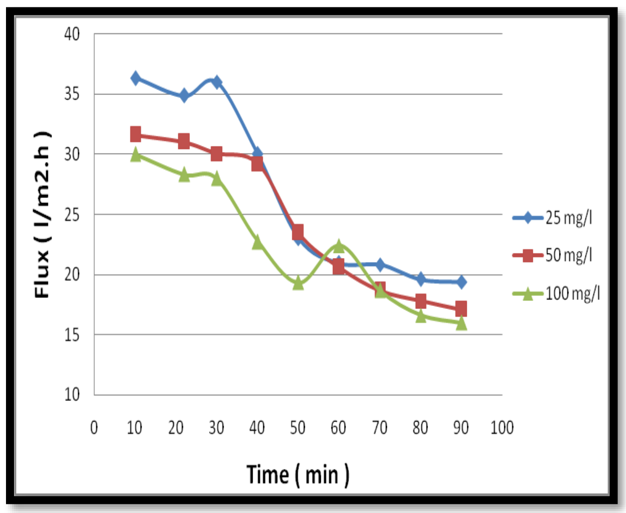

Fig. 6. Permeates flux with time for the Blue dye at the different concentration(P=7.5 bar)

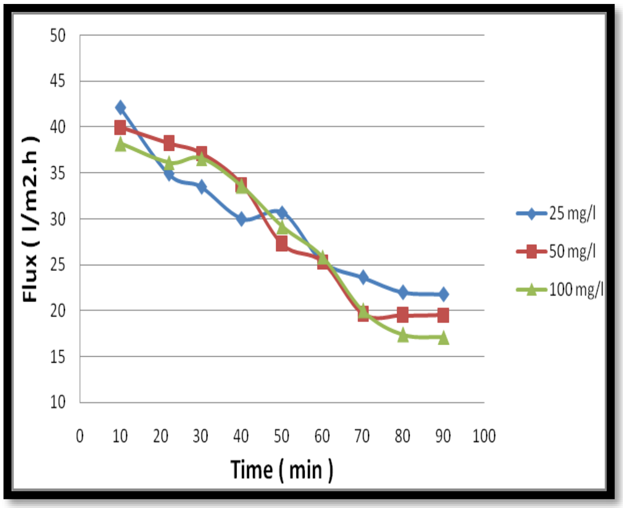

Fig. 7. Permeates flux with time for the Blue dye at the different concentration(P=10 bar)

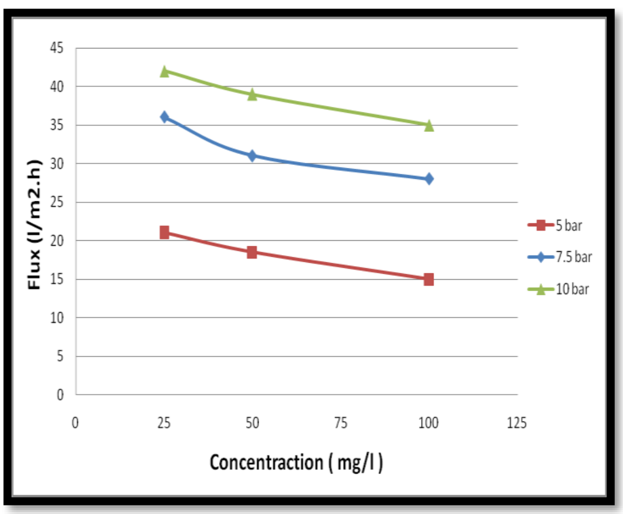

Fig. 8. The Relation between Concentration and Flux at different Pressure

5.5 Effect of the Pressure on the Flux

Reffering to the Figs. (5 to 7) when the pressure increasing from 5 to 10 bar the flux increases due to solution-diffusion model and overcoming the resistance at the membrane surface [6, 14] The operation time was 90 min for each run. The mass transfer coefficent and the concentration polarization layer increase with increasin operating pressure [6]

Fig. 9. shows the relationship between pressure and the flux for the blue acid, reactive and dispers dyes when the TDS is 3000 mg/l and dye concetrations are 100 mg/l. The fluxe increase linerlay with increasing the pressure at the same operating conditions.This is due to pressure gradient on driving force [17].

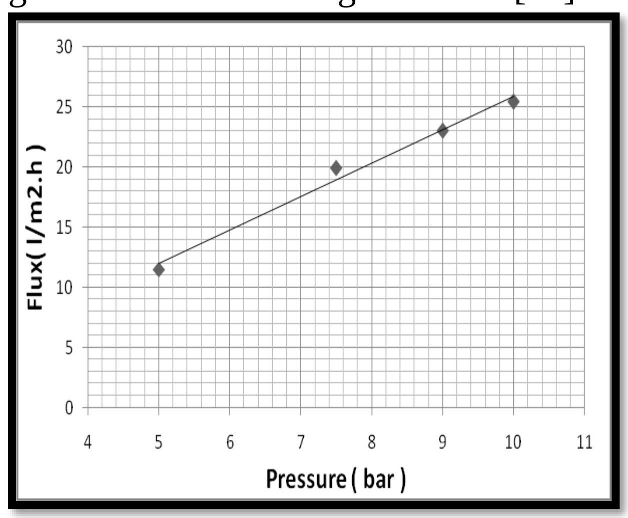

Fig. 9: The relation between pressure and flux at dye concentration = 100 mg/l

6. Conclusions

1. RO membrane proved to be an effective tool for removing acid, dye from wastewater.
2. Removal percent of acid, dye increases with increasing dye concentration and pressure in RO membrane.
3. Permeate flux from RO membrane is propotional with applied pressures. But it is inversely propotional to dye concentration

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ازالة الاصباغ الحامضية الزرقاء من مخلفات الصرف الصناعي باستخدام تقنية التناضح العكسي

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الخلاصة

هذه الدراسة لتقييم إزالة الصبغة الزرقاء الحامضية من مياه الصرف الصناعي باستخدام اغشية التناضح العكسي أجريت جميع التجارب باستخدام منضومة متكاملة تم تصنيعها باستخدام فلاتر مايكرو لازالة المواد العالقة بعد ذلك فلاتر التناضح العكسي (RO). وتستخدم هذه الأصباغ حاليا في مصنع نسيج الكوت في محافظة واسط / العراق. تمت دراسة ازالة هذه الاصباغ تحت عدة ظروف تشغيلية مثل الضغط والذي تراوح بين (5- 10) بار اضافة الى التركيز الاولي للصبغة والذي تراوح بين (25 - 100) ملغم / لتر لتغطية التراكيز المستخدمة في المصنع المذكوروبثبات الاس الهيدروجيني (pH) وضمن دراجة حرارة الغرفة.

اظهرت النتائج ان نسبة الازالة تزداد مع ازدياد الضغط المسلط الى نسبة تصل الى (٪ 98) والتركيز الابتدائي للصبغة الزرقاء خلال الزمن التشغيلي والذ هو 90 دقيقة. بينما الدفق يزداد مع ازدياد الضغط المسلط، اضافة الى ان الدفق يتناسب عكسيا مع زيادة تركيز الصبغة في المنظومة.

الاملاح الذائبة (TDS) ازيلت بكفاءة عالية وصلت الى ٪100 باستخدام اغشية التناضح العكسي.