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Studying Flux Decline in Hollow fiber Microfiltration unit using Domestic Wastewater

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Abstract

In this work, domestic wastewater taken from Alarein wastewater treatment plant Abha, Kingdom of Saudi Arabia, has been examined. Conductivity, pH, turbidity and TDS properties were measured for various samples. A 0.2µm tangential flow hollow fiber microfiltration system was used for wastewater treatment and permeates were re-tested. Results obtained showed reduction of various wastewater properties. Turbidity was noticed to have higher reduction value from 10.2 NTU to 1 NTU for wastewater sample. It has been found that permeate flux increases by increasing the transmembrane pressure and crossflow velocity. The impact of fouling was also studied by looking at the reduction of permeate flux with time at various operating conditions. From the results it has been found that the use of microfiltration system has proven reliability in improving wastewater quality to be utilized for drinking purposes.

Keywords: Hollow fiber microfiltration, permeate flux, turbidity, wastewater.

Introduction

Conventional treatment methods for wastewater no longer meet today's international standard because of high concentration, low efficiency and or high operational costs.Membrane technology is well known to be among the leading techniques recently developed for water and wastewater treatment, taking into consideration the positive environmental impact it generates. Membrane separation processes such as microfiltration can be accepted as a versatile separation process for domestics wastewater treatment. Energy efficient membrane based separation technologies becoming relevant in various processes and can be an alternative to many energy intensive processes such as distillation, extraction, etc.

Major problem associated with membrane based separation processes is the flux decline with time. This phenomenon occurs due to the build-up of solute concentration on the surface of membrane, known as concentration polarization and fouling. The utilisation of membrane processes for wastewater treatment is hampered by relatively low permeate flux resulted from the concentration polarization and fouling.

Several studies have been carried out to reduce concentration polarization[1,2]. These include; changing hydrodynamic conditions in the flow channel, hence causing sweeping action to remove deposited particles from the surface of the membrane. Whereas other researchers modified the membrane materials to cause a repelling action of the particles, thus prevent deposition. A novel method using a phase inversion technique to spin hollow fiber membranes applied in water turbidity removal from 1000 NTU to nil under various cross flow velocities was also developed by other researcher[3].

Influence of backwashing, flux and temperature on microfiltration and fouling rates were quantified as function of various operating parameters, i.e. flux and backwash intervals, as well as wastewater quality properties namely turbidity and temperature[4].

Addition of chemicals to act as coagulants has been applied with various ranges and doses that can go up to 2 mg/L on microfiltration-based indirect potable reuse (IPR) pilot plant to evaluate their impact on membrane reversible and irreversible fouling[5]. Problems of fouling and concentration polarization associated with the membrane were addressed by many researcher by introducing electrical field into the system[6-10].

Material and Methods

Materials: Domestic wastewater collected from Alarein Wastewater Treatment Plant, Abha Saudi Arabia, after wastewater clarification process, have been used in this study. Hollow fiber microfiltration system with nominal pore size 0.2µm obtained from Armfield (U.K.), has been used for the experiments.

Hollow Fiber Microfiltration Unit: The schematic of the continuous microfiltration unit is shown in figure-1. The filter unit is microfiltration type with total membrane area equal to 0.011 m^2. The bundle consists of 13 hollow fibre tubes with length of 0.27 'm' and 'each' housed in a clear plastic cylinder to enable both the fibres and the permeate to be observed visually. The fibres have an internal diameter of 1mm and pores of 0.2µm through which the permeate passes. There is a needle valve on both the retentate and permeate exists from the filter.

These are used to control the retentate and permeate pressures which are measures by pressure sensors (P2) and (P3).

From a feed tank which is made of acrylic, feed is pumped and allowed to flow tangentially over the membrane surface. A tubular heat exchanger is added to the microfiltration unit to enable constant temperature. There is a control console for controlling the pump and the tank stirrer, displaying system pressure and temperatures.

Characterization of tap water and wastewater was conducted by various apparatus: i. Digital pH meter: GPHR 1400(Germany). ii. Turbidity meter: ORION AQ 4500. iii. TDS meter: HM digital. iv. Conductivity meter.

Experimental Procedure: Clarified wastewater collected from the Alarein Wastewater Treatment Plant, Abha Saudi Arabia is used as a feed for the microfiltration unit. Larger suspended particles are removed by pre-filter installed within the apparatus. After selection of desired 'transmembrane' pressure, permeate volume was collected and measured using a measuring cylinder.

Tap water is used as a feed for microfiltration unit after conducting experiments with distilled water. Data of permeate volume were collected for different selected values of transmembrane pressure as a function of time. Afterwards, wastewater is used as a feed. Permeate volume was collected and measured continuously in a measuring cylinder and experiments were conducted for 30 minutes under different selected values of transmembrane pressure.

Results and Discussion

Distilled Water Analysis: Distilled water generated in the laboratory was tested firstly. Data were collected for transmembrane pressure ΔP equal to 0.2, 0.3 and 0.4 bar. Experiments were conducted for 40 minutes. Figure-2 shows the variation of permeate flux with time for selected values of transmembrane pressure.

Characteristics of Tap Water: Various characteristics of feed and permeate Tap water are presented in table- 1. After filtration process of tap water, the values of turbidity decreased from 0.94 NTU to 0.26 NTU which is an indicator of improving water quality using microfiltration unit.

Table-1
Characteristics of Tap water

Property	Tape Water as feed	Permeate
pH	8.63	8.21
Conductivity (mS/cm)	0.19	0.19
TDS(mg/L)	53	53
Turbidity(NTU)	0.94	0.26

Figure-3 shows the variation of permeate flux as a function of time, from which it has been noticed that at low values of ΔP equal to 0.2 bar, the decrease in the value of permeate volume with time is less as compared to that of ΔP equal to 0.4 bar. At the start of experiment, permeate volume collected is high, almost equal to 150ml at time t equal to 2 min for transmembrane pressure of 0.4 bar. After that it gradually decreases with time due to membrane surface fouling. Permeate volume reaches a value of almost 100 ml at time t equal to 20 min that is at the end of experiment.

Characteristics of wastewater: Various characteristics of raw and treated wastewater are presented in table- 2.

Table-2
Characteristics of wastewater

Property	Feed	Permeate
pH	7.68	7.73
Conductivity (mS/cm)	0.68	0.68
TDS(mg/L)	345	320
Turbidity(NTU)	10.4	1

Figure-4 shows the variation of permeate flux with time for selected values of transmembrane pressure equal to 0.2, 0.3 and 0.4 bar. Permeate flux decreases sharply with time for ΔP equal to 0.4 bar as compared to gradual decrease for ΔP values of 0.2 bar and 0.3 bar pressure.

Figure-5 shows the variation of permeate flux with time at a constant transmembrane pressure of 0.3 bar for distilled water, tap water and wastewater. For distilled water value of filtrate collected is very high and almost remains steady with time, which is what is expected due to the absence of any particulates. The values of flux for tap water and wastewater almost near and decrease is gradual. Tap water flux values are slightly higher than that for wastewater as evident from the curves.

Figure-6 shows the variation of permeate flux with transmembrane pressure. It is clear from all three curves that permeate flux increases as transmembrane flux increases. As time of filtration increases, value of flux decreases because of fouling of membrane surfaces. As is mentioned in the literature, fouling is the major problem associated with membrane based separation processes.

Conclusion

In this investigation tap water and wastewater were collected and characterized. It was found that wastewater has the characteristics of high total solid contents and turbidity. The level of contamination is proven to be high, thus needs proper treatments before utilization. The research findings may be summarized as follows: i. Using this treatment method, it is viable to reduce turbidity of tap water from 0.96 NTU to 0.36

NTU. ii. For wastewater, turbidity can be reduced from 10.2 NTU to 1 NTU which is an internationally acceptable value. iii. A desired permeate flow rate and quality of filtrate can be obtained under proper operating conditions. iv. Permeate flux can be increased by increasing the transmembrane pressure and crossflow velocity. v. Permeate flux decreases with time due to the fouling of the membrane surface. vi. Fouling of membrane surface can be minimized using various techniques.

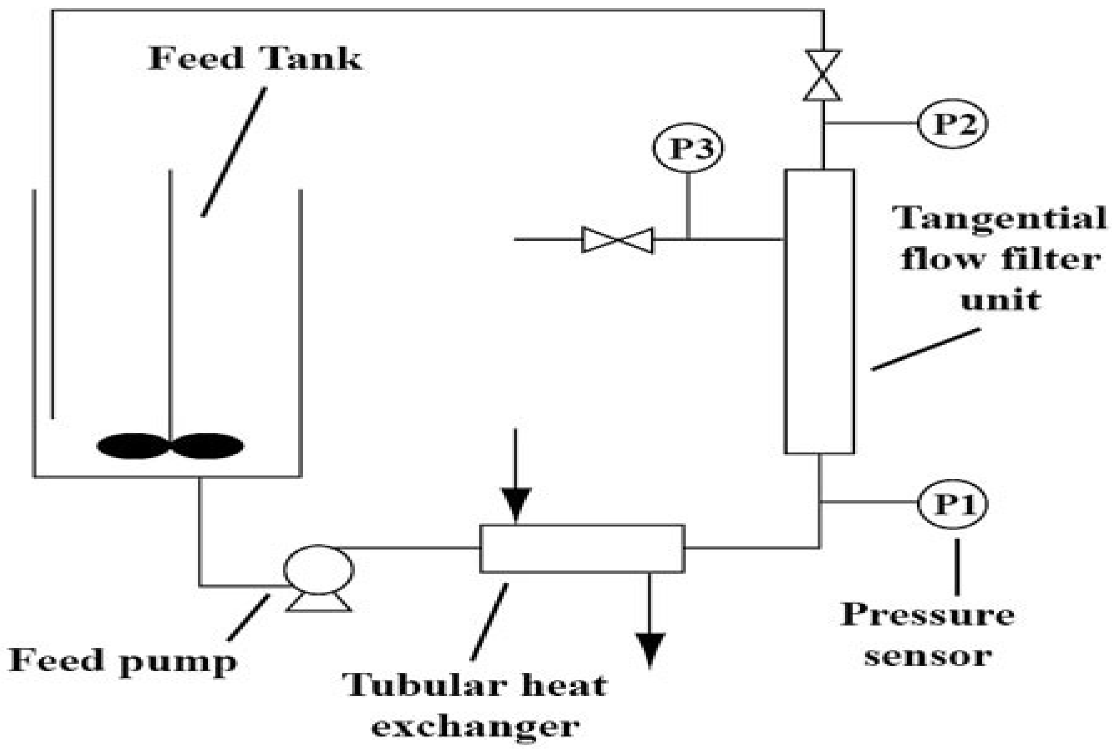

Figure-1
Schematic diagram of hollow fiber microfiltration unit

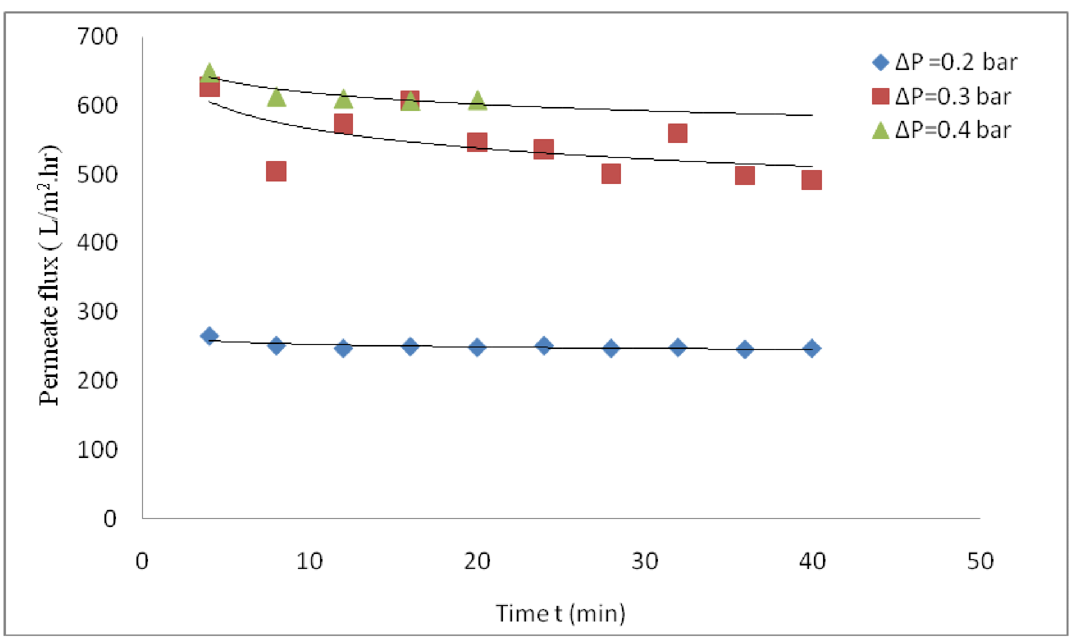

Figure-2
Permeate flux vs. time curve for distilled water

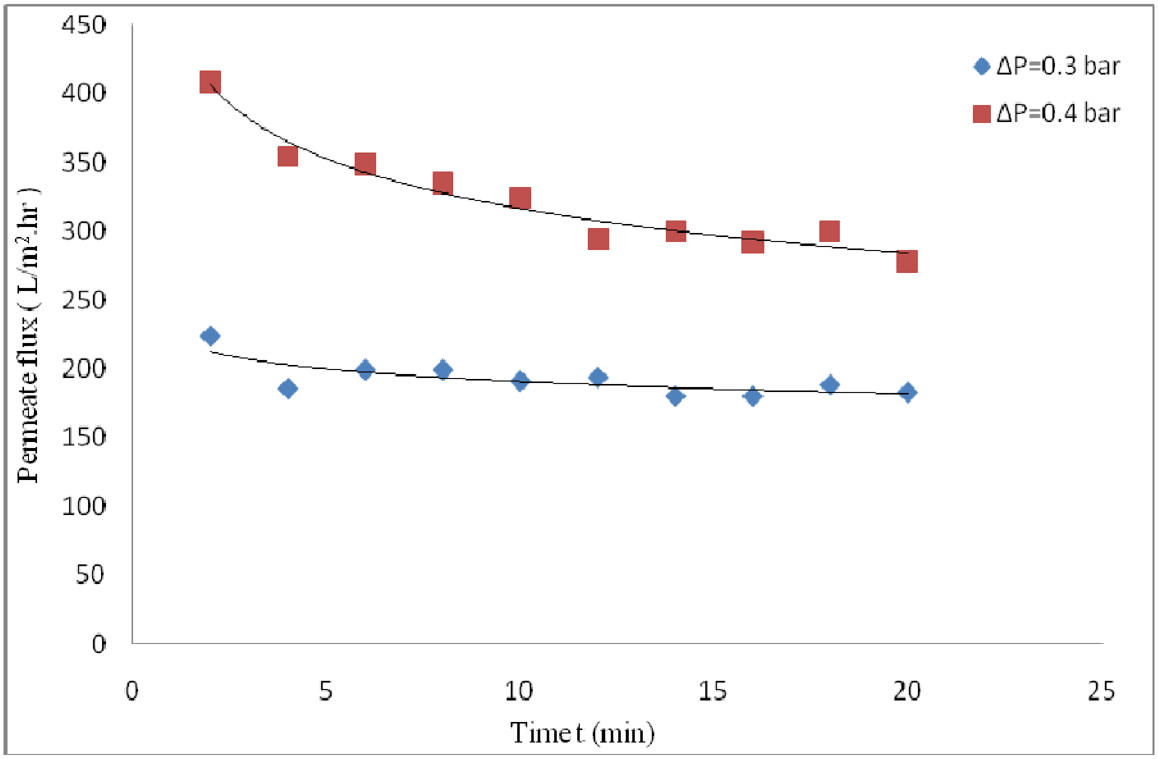

Figure-3
Permeate flux vs. time curve for tap water

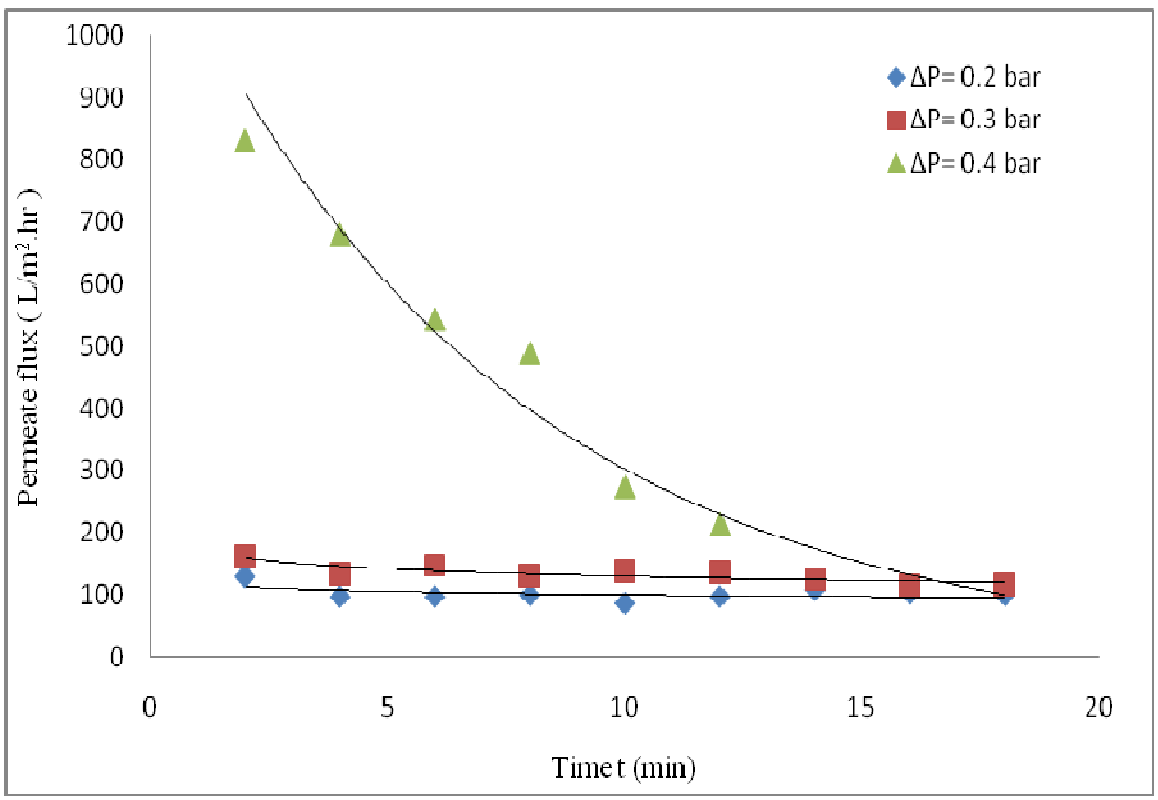

Figure-4
Permeate flux vs. time curve for wastewater

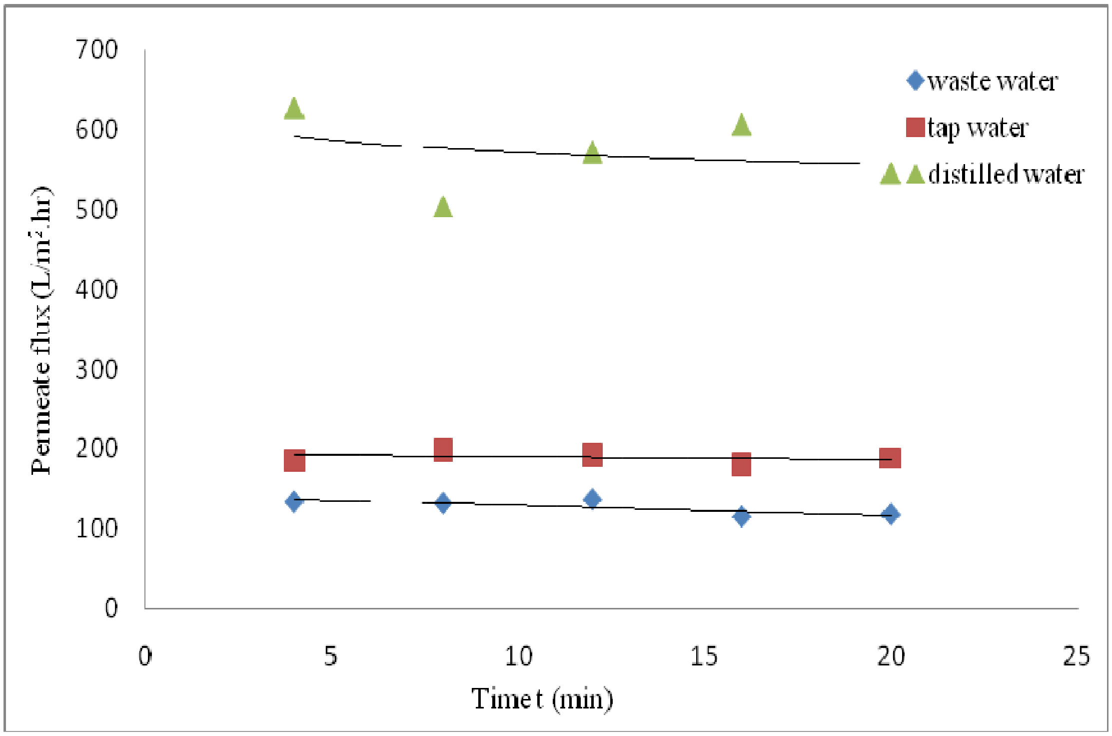

Figure-5
Permeate flux vs. time curves at T.M. pressure of 0.3 bar

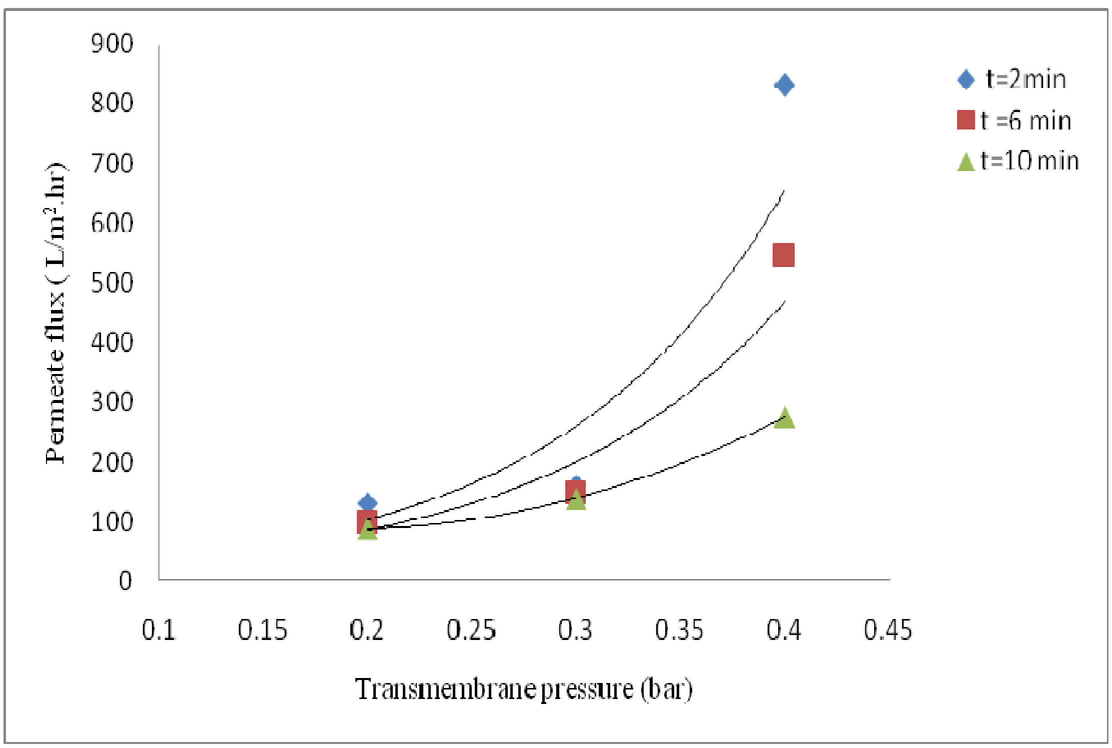

Figure-6
Permeate flux vs. transmembrane pressure curve

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