4th International Conference on Water Resources and Arid Environments (ICWRAE 4): 471-474
5-8 December 2010, Riyadh, Saudi Arabia

Reverse Osmosis for Treatment of Industrial Wastewater

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Abstract: Industrial wastewater components show different degrees of environmental nuisance and hazardous contamination due to their chemical characteristics as well as excessive concentration. Reclamation of wastewater is becoming a major goal in countries with water scarcity. The application of reverse osmosis for treatment of various wastewaters including industrial effluents is a promising alternative for water recycle and reuse. This paper deals with the experimental investigation of feasibility of wastewater treatment using reverse osmosis (RO) process for water reuse in an industrial zone in Iran. Reverse osmosis polyamide membrane was challenged with effluent of Faraman (Kermanshah, Iran) wastewater treatment plant. The effects of various operating conditions such as transmembrane pressure, cross flow velocity and temperature on membrane performance in terms of water flux and COD rejection were elucidated. The results indicate that the quality of the produced water is high enough for application in the industrial plants. In particular the COD removal was increased from 64 to 100% as temperatures increased from 15 to 45°C for the transmembrane pressure of 20 bars and cross flow velocity of 1.5 m/s.

Key words: Membrane • Reverse osmosis • COD • Wastewater • Industrial water

INTRODUCTION

Membrane processes are a promising technology for wastewater reuse [1]. They offer a number of advantages including resistance against the fluctuations (shocks) in the feed, higher product quality, lower land requirements, the possibility to use mobile units [2] and reduced energy consumption [3].

Reverse osmosis (RO) have been applied for treating a wide variety of industrial effluents. The difference between various membrane processes is the size of components that can be separated. The selection of membrane type depends on the characteristics of the wastewater and to the required efficiency.

Treatment by reverse osmosis (RO) reduces high levels of dissolved solids but has limitations when used for the removal of organic compounds from effluents of the chemical industry [4]. The process has been applied in treatment of municipal wastewater. An appropriate index for showing the amount of organics in water is chemical oxygen demand (COD). This is a test for assessing the quality of effluents and wastewaters prior to discharge. Reverse osmosis may be employed for COD polishing [5]. If the treated water is drained into natural water, the COD has to be below 125 mg/L, if it is released into sewer the limit is 800 mg/L [6]. Reverse osmosis membranes may decrease the COD of the effluent up to 99% [7]. The quality of water or wastewater plays an important role in industrial processes and local ecology. Some special cases including boilers require high quality water due to the higher temperature and pressure conditions.

The aim of this study was elucidating the optimum operating conditions for maximum removal of impurities in treatment of industrial wastewater using an appropriate reverse osmosis membrane. In particular the complete removal of COD was of interest. The waste water was sampled from Faraman sewage treatment plant based in Kermanshah (Iran).

MATERIALS AND MATHODS

A bench-scale cross-flow batch concentration apparatus was used for all experiments. Permeate was taken out of the loop and concentrate was returned to the tank. A high-pressure pump was used. The membrane

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with the active area of 0.002 m^2 was settled on a resistant compact foam layer, to protect it against deformation and displacement. There were two oil pressure gauges (0-60 bar) on the flow line.

Thin-film composite polyamide reverse osmosis membrane, FT-30, (Filmtec Company, USA), was used in this study. Maximum operating pressure is 6.9 MPa, maximum operating temperature is 45°C. pH range for continuous operation is 2 to 11 and for short-term cleaning is 1 to 13.

The wastewater was sampled from Faraman wastewater treatment plant (Kermanshah, Iran). The treated sewage through the biological process was used as feed in all experiments. The COD of the feed varied between 150 and 350 mg/lit. In the biological step the microorganisms were applied to remove the organic material dissolved in the sewage. The biological refinement was carried out in the aerating basins by the aerobic bacteria, where the bacteria feed on the organic matters by consuming oxygen. This process causes the contamination to be decreased. Finally, the sludge of the aerating basin enters the second sedimentation (deposit) stage. The pH of solution was in the range of 7–8.

The feed of the experimental samples were analyzed for COD, TDS, pH and other contaminants. COD was performed by the dichromate closed refluxed colorimetric method using a spectrophotometer (APEL-PD-303). Concentrations of cations were determined by Atomic Absorption Spectrophotometery (AA-6300 SHIMADZU). Inions analyses were performed using Ionic Chromatography (761 Compact IC, Metrohm). Concentration of Ca^{2+} and K^+ and Na^+ sample were determined by flame photometer Spectrophotometer (Corning 400).

RESULTS AND DISCUSSION

The water flux is one of the most important parameters in the evaluation of the performance of a filtration system. When the level of solute retention is met, the permeate flux turns to the fundamental factor in process optimization. The higher the permeate flux, the lower the necessary filtration area. The COD retention is influenced by the transmembrane pressure, temperature, cross-flow velocity and operation time. Significant reduction in flux for the first 90 min indicates the development of fouling layer. The flux reduction from 22 to 11 kg/m^2.hr was observed. This is due to the deposition of small particles and colloidal on the membrane surface which led to the membrane fouling. The flux reached a constant value of 11 kg/m^2.hr after 270 min.

Fig. 1 represents the variation of COD rejection during time at constant feed temperature, transmembrane pressure and cross-flow velocity. This was improved from 72 to 100% during time. A layer of particles and macromolecules is deposited on the membrane surface, which leads to cake formation or a "secondary membrane". This layer increases the hydraulic resistance and decreases flux. Meanwhile the layer prevents the passage of the species through the membrane.

As temperature increased from 15 to 45°C, the flux was drastically increased from 16 to 34 kg/m^2hr (Fig. 2). The variation of permeate flux with temperature is usually explained by the variation in the viscosity of the effluent. In the range of 15 to 45°C, the temperature strongly influences the permeate flux. This can be represented by Arenius equation. Moreover increasing the temperature enhances the diffusivity, which results in an increase in permeation flux.

During filtration, solvent flux is increased and solute flux stays unchanged. This leads to high rejection of COD in the permeate. Fig. 3 indicates that the removal of COD was enhanced by increasing the temperature. At 45°C, COD removal reached to 100%.

Generally, the water used for industrial plants must be clear, colorless, without suspended solids, oils and aggressive chemicals. Other parameters are low content of hardness, alkalinity and carbon dioxide.

The water requirements for power plants are based on providing water for cooling and water as a source of steam in boilers. Typically, the quality of water needed for boiler has to be higher compared to the cooling tower. Colloidal deposits decrease boiler efficiency and also cause premature failure of turbines. Scale is usually calcium and magnesium carbonate that precipitate as the ions are concentrated in the boiler.

The FT30 reverse osmosis membrane has an excellent performance in a wide variety of applications. FT-30 membranes could remove 99% inorganic salts and RO product could meet the requirements of reuse. Removal percentage of anions, cautions, organic and inorganic matters are shown in Fig. 4. The most removed of the samples is about 90-95% and removal rate of total dissolved solid (TDS) is more than 95%. Permeate water with high quality will be used as feed in cooling towers and boilers.

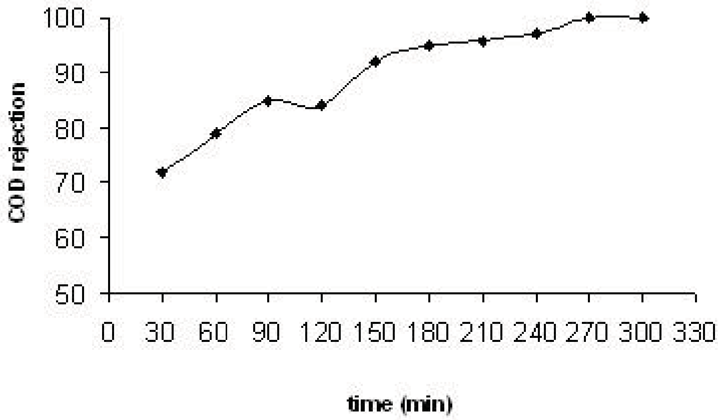

Fig. 1: COD rejection for filtration of wastewater using FT-30 RO membrane (pressure 15 bar, temperature 25^{0}C cross-flow velocity 1 m/s)

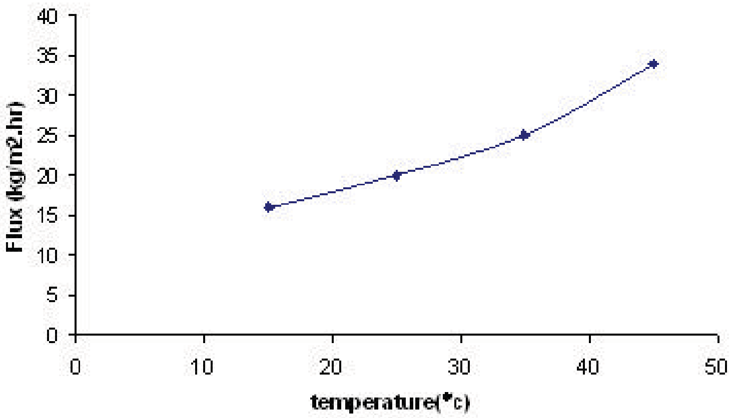

Fig. 2: Effect of temperature on permeate flux for polyamide (FT-30) membrane

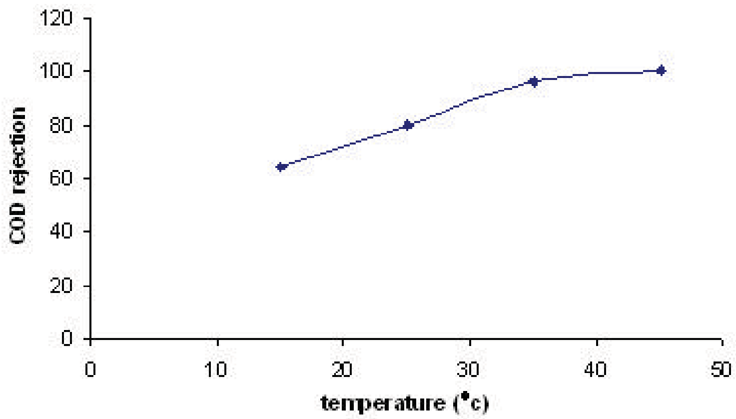

Fig. 3: Effect of temperature on COD retention for polyamide (FT-30) membrane

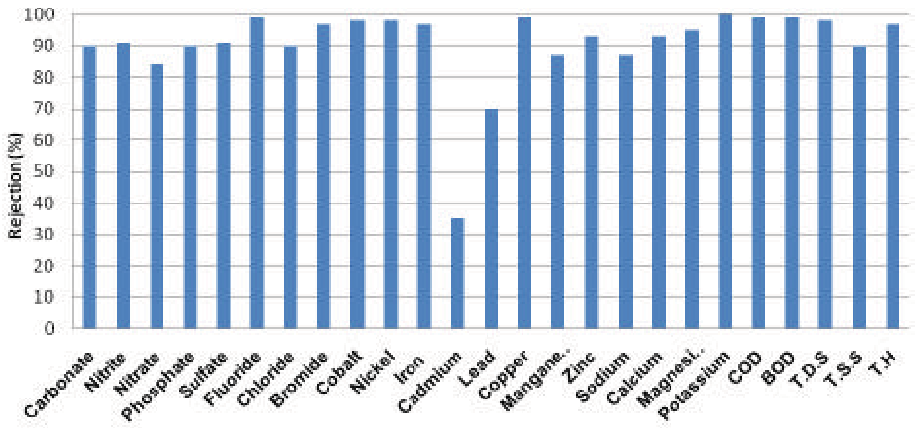

Fig. 4: Removal percentage for treatment of industrial wastewater using FT-30 polyamide membrane

CONCLUSION

The effect of operating conditions on permeation flux and COD rejection were studied. It is evident that a RO membrane could drastically reduce the COD concentration to a value of 100% and showed that reverse osmosis is effective for reduction of organics, colloidal, suspended solids, inorganic ions, from effluent of waste water plant. According to the results, permeate water with high quality is in according with the standard which will be used as an input feed for cooling tower and boiler.

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