Treatment of Textile Wastewater Using Nanofiltration

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Abstract

The discharge of the synthetic dyes in textile industries is considered to be a major environmental problem due to aesthetically undesirable in receiving waters. Therefore, treatment processes for removing of dyes from textile effluents have become important. Nowadays, removal of dyes is carried out generally by physical and chemical methods. In this study, synthetic textile wastewater was prepared using cationic dye (Methylene Blue) and with addition of other chemicals. The treatment of textile wastewater in the cross flow membrane system was investigated. Flat sheet polymer type nanofiltration membrane (NF) at constant working pressure was used to remove COD (chemical oxygen demand), color, turbidity and conductivity from effluents. Removal efficiencies of COD, color, turbidity, conductivity of samples at 15 bar were found to be 98%, 98%, 100%, and 95%, respectively. Membrane processes can be used to treat textile wastewater and reuse of treated wastewater in the process as process water can be achieved as advanced treatment.

Keywords: Synthetic textile wastewater, methylene blue, COD, color, nanofiltration

Introduction

Textile industry is one of the biggest industries of Turkey and it consumes some amount of water. As there are several methods and technologies used in this sector due to the different raw materials and various chemicals, the wastewaters obtained vary related to the products produced (Fersi et al, 2005).

The textile industry wastewaters discharges contain many types of organic dyes, common inorganic salts, heavy metal ions and solvents and can cause harmful effect to the aquatic ecosystems. Several chemical and biological treatment methods such as adsorption, coagulation, advanced oxidation and biodegradation have been used for removal of these type of wastewater (Yagub et al., 2014; Huang et al., 2014). However, adsorption and coagulation usually generate huge amount of sludge, and oxidation and biodegradation are invalid to the heavy metal ion and inorganic salt removals. Thus, effective technology for textile wastewater treatment can be preferred over conventional treatment methods.

Membrane processes are alternative separation technologies to the conventional separation techniques such as distillation, adsorption, absorption and extraction. Membranes can be made of polymer, glass, metal or liquid, and can be porous/nonporous, symmetric/asymmetric or composite. Membrane processes provide several advantages such as high selectivity, low energy consumption, moderate cost to performance ratio and modularity. Nanofiltration (NF) as an environmentally-friendly membrane technology has gained much attention for some industrial applications including food, pharmaceutical, petrochemical industries and wastewater treatment (Ong et al., 2014). Generally, it is much more efficient than ultrafiltration (UF) with regard to rejection and also shows the higher permanence than reverse osmosis (RO) (Gozálvez-Zafrilla et al., 2008; Alcaina-Miranda et al., 2009). NF membranes are especially suitable for dealing with positively charged solutes such as cationic dyes and metal ions from textile wastewaters due to electrostatic repulsion.

The aim of this research was investigated using cross flow NF membrane to treat synthetic textile wastewater containing cationic dye (methylene blue) and with addition of other chemicals. Flat sheet polymer type NF membrane at constant working pressure (15 bar) was used to remove COD, color, turbidity and conductivity from effluents (Sathian et al., 2014).

Materials and methods

Chemicals and membrane

Methylene blue (cationic dye) was supplied by Sigma-Aldrich (Belgium). Fig.1 shows the chemical structures of this dye. NaCl and Na_2SO_4 (analytical grade) were obtained from Sigma-Aldrich (Belgium). All the chemicals were used without any further purification.

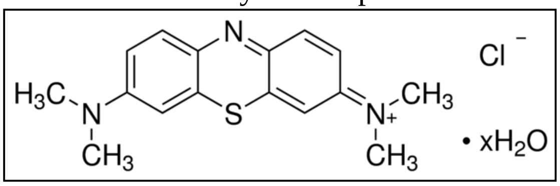

Fig. 1: Chemical structure of Methylene blue dye (Sarioglu and Atay, 2006).

Methylene blue is a cationic dyestuff, the chemical formula is "$C_{16}H_{18}N_3SCl$", the molecular weight is 373,9 g mol^{-1}. It is used for coloring in textile industry and also for preventing fungus reproduction in fish breeding farms. The spectrum of the wavelength scanning in the spectrophotometer is given in Fig 2. The λ_{max} value according to this scan is 663 nm.

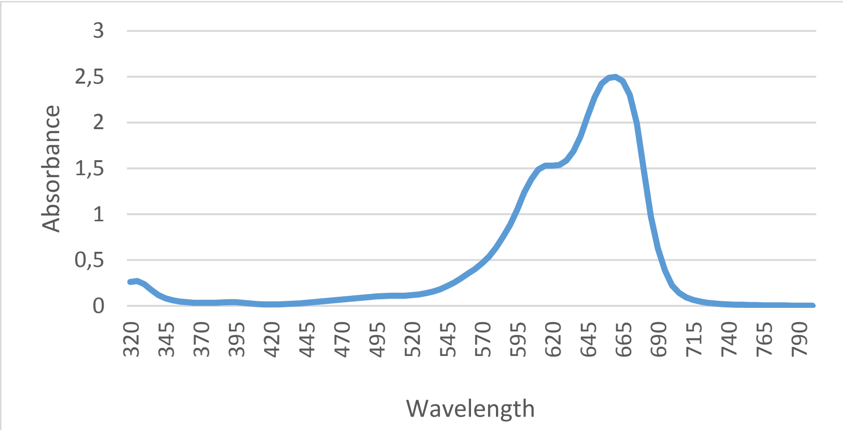

Fig. 2: The λ_{max} value of methlyene blue.

Synthetic textile wastewater was prepared using metylene blue (100 mg/L) dye with addition of chemicals (Table 1).

Table 1: Synthetic influent composition

Component	Concentration (mg/l)
$C_6H_{12}O_6$ (glucose)	1000
NaCl	22
$CaCl_2.2H_2O$	22
$MgSO_4.7H_2O$	0,075
$(NH_4)_2HPO_4$	0,05
K_2HPO_4	67

Table 2: Properties of NF membrane used in this study[a]

Membrane	GE osmonics
Thin film (DL)	NF
MWCO[b]	150-300 dalton
Pure water pressure	220 psi (25 C)
pH	2-10

a Data provided by the manufacturer.
b Molecular weight cutoff (MWCO)

Membrane experiments

Cross-flow filtration was performed with a flat membrane module (SEPA CF Cell) presented in Fig. 3. The membrane area was 0,014m^2. The membrane module was equipped with a temperature control system and the temperature was kept at 18±20°C. The volume of the feed solution was 6-6.5 L. In this study, organic polymer thin film NF membrane (150-300 dalton moleculer cutoff weight) was used. The experimental set-up is shown in Fig. 4.

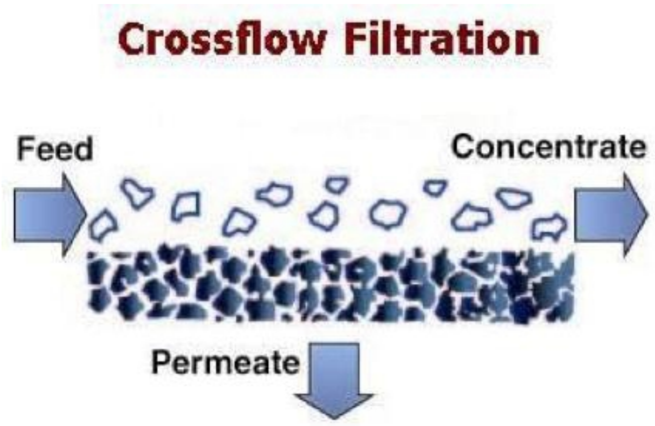

Fig. 3: Cross flow filtration mechanism

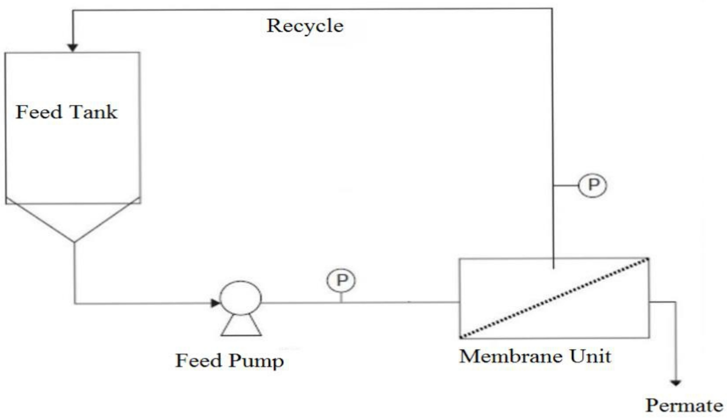

Fig. 4: Cross flow membrane unit

The rejection coefficients (R) for the NF membrane were calculated from the measured feed (C_f) and permeate concentration (C_p) using the following equation:

$$R\ (\%)=(1-C_p/C_f)\times 100 \qquad (1)$$

In cross-flow membrane filtration experiments, permeate flux was monitored by measuring the time at which a known amount of permeate was collected in a graduated cylinder. Permeate flux measurements were periodically done till steady state by simply measuring the volume of filtrate collected per unit time and dividing it by the membrane surface area. COD, color, conductivity and pH parameters were measured in each timely taken filtrate samples.

The sample was analyzed for color, COD and turbidity. COD analyzes were carried out by closed reflux titrimetric method according to

APHA standard methods (APHA, 1995). The color values of the samples were measured by a Shimadzu UV-spectrophotometer. According to the measured values, the color removal efficiency is calculated with the help of Equation 2. Conductivity evaluated with a Benchtop Conductivity Meter. Turbidity was measured using Turbidimeter.

$$\text{Efficiency} = \frac{C_0 - C}{C_0} \qquad (2)$$

C_o is the initial dyestuff concentration, C is the dyestuff concentration of the sample.

The filtrate flux (J_w) was calculated from the time to collect a fixed volume of permeates.

$$J_w = V/A.t \qquad (3)$$

where V is the volume of permeate collected during the time interval t and A is the effective membrane area. The observed rejection (R_s) of dyes was calculated as:

$$R_s\ (\%) = ((C_{f,s} - C_{p,s}) / C_{f,s}) x100) \qquad (4)$$

where $C_{f,s}$ and $C_{p,s}$ are the solute concentrations in the feed and permeate, respectively.

Results and discussion

NF membrane performance

After preparing of synthetic textile wastewater, wastewater characteristics were determined. In this study effect of pressure on removal efficiency was ignore. Constant maximum pressure (15 bar) was selected for determining of performance of this NF membrane unit. Cross-flow membrane filtration experiments were carried out in two modes; a) total recycle b) concentration mode. In this study, in order to determine removal efficiencies of pollutant parameters (COD, color, pH, conductivity, turbidity) experimental results of concentration mode was given. The second mode of cross-flow tests were in concentration mode at which the retentate is returned to the feed vessel but permeate is withdrawn from the system (Figure 4). Fig. 5 shows the profiles of flux as a function of time (h). The flux starts to become constant after 4 h working time. As expected, the clean water permeability decreased with running time.

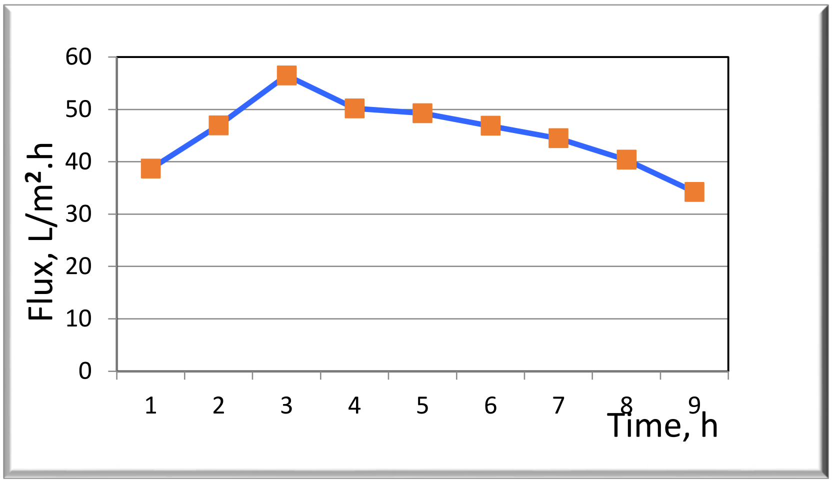

Fig. 5: Flux for NF membrane as a function of time (pressure: 15 bar)

Initial and effluent of cross flow NF membrane (permeate) samples were analyzed for COD, color, conductivity, turbidity and pH. Results was given in Table 3.

Table 3: Synthetic wastewater NF membrane system influent and effluent values

Parameters	Feed	Permeate
COD (mg/L)	2300	50
Color (mg/L)	100	2,30
pH	5	5,15
Conductivity (μS)	125,5	22,3
Turbidity (NTU)	3,40	0,01

Nanofiltration (NF) membranes have been used previously for the recovery of dyes, salts, and water from textile wastewaters with high salinity. This NF membrane allows for high permeation of salts and organic compounds. Thin film NF membrane was proposed as an alternative to ultrafiltration for the separation of aqueous mixtures of dye/Na_2SO_4. Similar comment was given in literature using tight ultrafiltration membrane (Saffaj al., 2005).

Conclusion

The results of this study demonstrate that textile wastewaters containing COD and color can be removed in cross flow NF membrane system Flat sheet polymer type NF membrane at constant working pressure (15 bar) was used to remove COD, color, turbidity and conductivity from effluents. Removal efficiencies of COD, color, turbidity, conductivity of samples at 15 bar were found to be 98%, 98%, 100 %, and 95%, respectively. Membrane processes can be used to treat textile wastewater and reuse of treated wastewater ın the process can be achieved as advanced treatment.

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