

An Experimental Study on Dye Water Treatment using Nanoporous Membrane Process

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Abstract—Water has always been perceived as a gift from the gods as it rained from the heavens. In addition to bacteria, viruses and inorganic minerals, our drinking water today contains around two hundred deadly commercial chemicals making water a chemical cocktail that is unsuitable for human consumption. The biological methods have been used so far for the treatment of wastewater consisting of dyes discharged by textile industries. In the present study, nanofiltration technique has been employed for the removal of different dyestuffs. The rate of dye removal by the ceramic membrane was evaluated experimentally for four classes of dyes such as acidic, disperse, reactive and direct in red and blue color. Acid and reactive dyes were selected, based on the usage rate in industry. The dye absorbance was measured by UV- Spectrophotometric method. The effects of dissolved salts and operating pressure on the permeate flux were analyzed. It was observed from the studies that the presence of salt in the dye solution particularly NaCl has resulted in a higher color removal with a permeate flux decline

Keywords—Wastewater, Synthetic dyes, permeate flux, Membrane separation and Nanofiltration.

I. INTRODUCTION

SO far, our earth is the only planet in the whole universe, accredited to have life. One of the prime reasons, which support life in our mother-planet, is water. But, anthropogenic activities have caused a great harm to the quality of our lifeline, i.e. water. Because of fast depletion of the freshwater resources, there seems to be a crisis of the same. Water pollution is a global concern and, it is the high time that we realize the gravity of the situation. Removing pollutants from water is the crying need of the hour and developing a cost effective and environmentally safe method to achieve the same is a challenging task for chemical engineers. The environmental challenge for the textile industry is associated with liquid waste, which tends to dominate over air-emissions and solid wastes in terms of the severity of environmental impacts. A typical textile unit generates various types of wastewater differing in magnitude and quality. The wastewater from printing and dyeing units in a textile plant are often rich in color, containing residual of reactive dyes and chemicals, and needs proper treatment before releasing into the environment. Large quantities of wastewater which contains toxic organic residues are generated from the textile and dye

manufacturing processes. Synthetic dyes are considered the most difficult to treat because they contain complex aromatic molecular structures, which make them more stable and more difficult to be biodegraded [1, 2]. Due to their chemical structure, dyes are resistant to fading on exposure to light, water, and many chemicals [3]. There are many structure varieties such as acidic, basic, disperse, azo, diazo, anthroquinone based, and metal complex dyes. These dyes are very stable and can be decomposed only at temperatures higher than 200°C. For this reason, synthetic dyes often receive considerable attention from researchers in textile wastewater treatment processes [4]. The present work will focus on nanofiltration (NF) membranes. NF is characterized by a membrane pore size between 0.5 and 2 nm and operating pressures between 5 and 40 bars. It is used to achieve separation between sugars, other organic molecules and multivalent salts on one hand and monovalent salts, ions and water on the other. The importance of these membrane processes can be judged from the membrane area installed in various industrial sectors. Among the conventional methods for removal of color from wastewater, viz. chemical coagulation, flotation, chemical oxidation and adsorption, adsorption is the most common technique. But it is inherently a slow process and its performance is limited by the equilibrium. Thus there is a definite need to find alternative treatment processes. Membrane techniques hold great promise in this field, as they have the potential to either remove the dyestuff or allow reuse of the auxiliary chemicals used for dyeing or to concentrate the dyestuffs and auxiliaries and produce purified water. Microfiltration is suitable for removing colloidal dyes from the exhausted dye bath and the subsequent rinses. Ultrafiltration is effective as single-step treatment of secondary textile wastewater. Nanofiltration (NF) allows the separation of low molecular Weight organic compounds and salts, with an appreciable softening effect.

II. MATERIALS AND METHODS

In this study, synthetic Dye solutions were used for experiments. Four classes of dye with the highest usage rates in textile Industries reactive, disperse, acidic and direct in blue and red. All the solutions were prepared with tap Water. The experiments were performed with a nanofiltration pilot plant as shown in Fig.1 Commercially available ceramic membrane modules Ceram INSIDE (TAMI Industries) were used in the experiments. The modules were of the tubular single- or multi-

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channel type with a titanium oxide active layer. Technical parameters of the experimental modules used in the tests are given in table 1.

Nanofiltration Process

The transport and separation properties of the ceramic modules were determined using the systems. The installation presented in Fig. 1, consists of a membrane module (1), feeding tank (2), pressure pump (3), pressure sensors (4), and valves (5). Additional sensors protected the setup against an unexpected pressure increase. Experimental solutions were passed through a filter prior to the nanofiltration module.

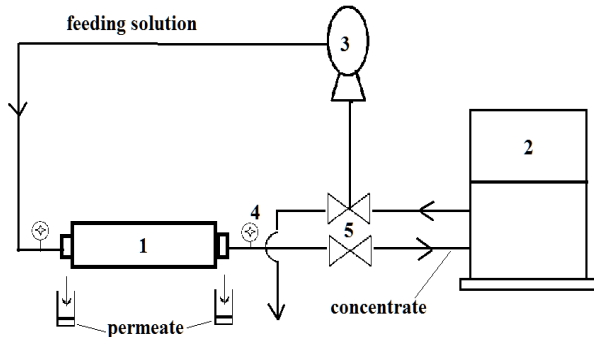


Fig. 1 Laboratory NF installation: 1-Ceramic membrane module, 2-Feeding tank, 3-Pressure pump, 4-Pressure sensor, and 5-Valve.

Prior to each cycle, the membrane module was treated with water until constant permeate volume flux was established. Permeate volume fluxes and retention coefficients were determined with respect to the experimental dyes after steady flow conditions were achieved. The permeate flux was measured and the concentration of dye was analyzed in the permeate and concentrate at 10 minute intervals during the long-term experiments. Permeate volume flux (J) is calculated using equation(1):

$$J = \frac{V}{t \cdot A}, \text{ m}^3 / \text{m}^2 \text{ day} \quad (\text{eqn.1})$$

Where V is the permeate volume (m^3), t stands for time (day), and A denotes the effective membrane surface area (m^2). The dye retention coefficient is determined using equation (2).

$$\text{Dye rejection (\%)} = \frac{c_k - c_p}{c_k} * 100 \quad (\text{eqn.2})$$

Where C_k and C_p denote the dye concentration (g/m^3) in retentate and permeate, respectively.

Synthetic Wastewater Preparation

Dye solutions were synthesized in different concentrations of 5 to 100 mg/L by mixing of every individual dyes powder in tap water.

Experimental procedure

Nanofiltration experiments were carried out in different concentrations 5 to 100 mg/L of each dyes, and the nanofiltration consist of single concentration step. In all steps, samples were collected for analysis every 10 minutes within 2 h. All experiments were carried out in 2 h.

Sample analysis

Samples of permeate and raw wastewater were collected during experiments. All the experiments were carried out based on Standard Method. The color was determined spectrophotometrically at a dominant wave length by using a UV-Vis spectrophotometer.

III. RESULTS AND DISCUSSION

Effect of pressure on dye removal

With increasing the pressure, flux is expected to increase accordingly due to diffusion model. Increase in feed pressure will increase the driving force, overcoming membrane resistance. The effect of membrane pressure on dye removal in permeates flux shows increase in flux with increasing the pressure. In this investigation, increasing the pressure from 7.5 to 10 and 12 bars leads to an increase in the permeate flux. Higher flux values were obtained at 12 bars for applied dyes. The results are shown in Figs. 2 and 3. In this step, acid red and acid blue dyes were used for all experiments. After 2 hours operation time of each run, permeate flux decline was increased due to concentration polarization. Fig. 4 shows the effect of pressure on dye removal in nanofiltration membrane. Dye removal increased with increasing pressure. Dye removal was increased up to 98 % at 12 bars for both acid red and blue dye. This may be attributed to mechanical compaction of membrane at higher operating pressure. Dye removal for reactive blue was obtained higher than reactive red. Feed dye concentration was set at 50 mg/L in all experiments in this step.

Effect of salt concentration

Figs. 6 and 7 shows the variation of permeate flux with time in dye-salt mixture solutions. The nature of the membrane material, the type and concentration of solute and pH are the parameters that can affect the dye removal in different TDS concentrations. In each case, different electrostatic interactions take place between dye and NaCl and membrane. In the three runs,

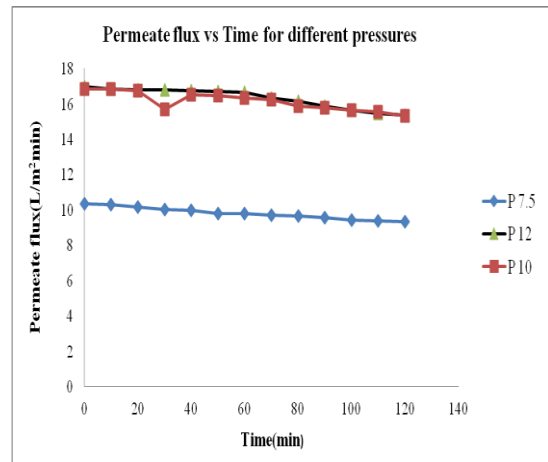


Fig.2 Variation of permeate flux with time for acid red dye at different pressures

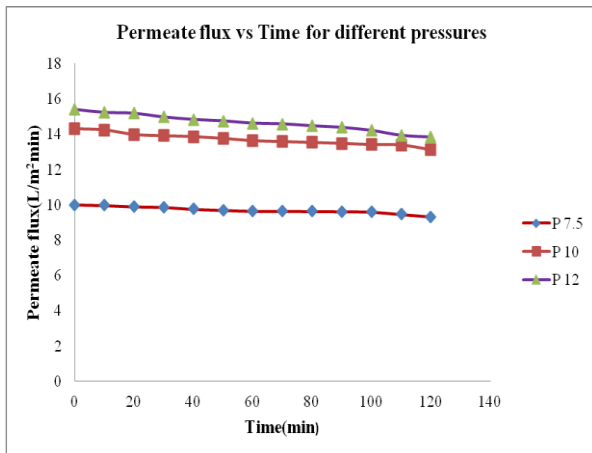


Fig.3 Variation of permeate flux with time for acid blue dye at different pressures

TDS of solutions concerns to NaCl concentration was set at 1000, 2000 and 3000 mg/L respectively for both acidic red and blue dye. The concentration of dye was fixed at 50 mg/L and pressure was fixed at 10 bars. All the experiments were carried out for 2 hours to reach the steady state conditions. As expected, increasing the salt concentration resulted in a lower permeate flux. Permeate flux is directly related to the feed pressure and osmotic pressure differences. Osmotic pressure increases with increasing salt concentration which leads to decreases of permeate flux. Flux decline at high salt concentration was lower than the flux decline at low salt concentration. Fig. 15 shows the results of variation (%) dye removal with salt concentration. Although flux values were high for low salt concentrations, it decreased with time.

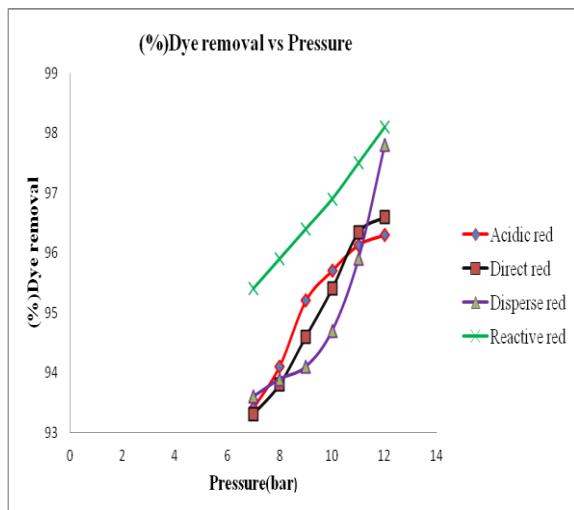


Fig.4 Variation of (%) dye removal with different pressure for red dyes

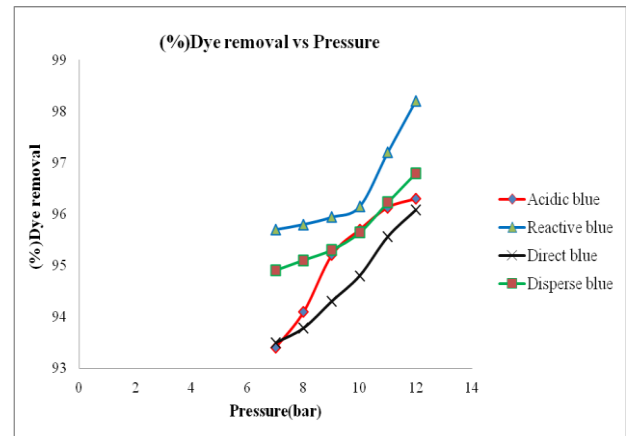


Fig.5 Variation of (%) dye removal with different pressure for blue dyes

One of the reasons for flux decline in high salt concentrations was decreasing of dyes solubility resulted in increasing of dye aggregation. Dye removals in all experiments were obtained up to 98.5 %. It was evident that the presence of NaCl has resulted in a higher color removal; this might be due to the concentration polarization layer formed by the salt that acts as an additional barrier to the passage of the color together with the barrier formed by the dye concentration polarization layer. Fig.8 shows Variation of (%) dye removal with TDS for red and blue dyes.

IV. CONCLUSIONS

Higher flux values were obtained in pressure 12 bars for applied dye. Dye removal was increased with increasing the pressure and maximum dye removal percentage was obtained nearby 98.5% in 12 bars. Dye removal for acid blue was higher than acid red. As a result, the presence of NaCl had resulted to a higher color removal that concerns to the concentration polarization layer and in the most of experiments, dye removal percent was obtained up to 98.5 %. Permeate flux was declined ($L/m^2min.$) in high salt concentrations due to dye aggregation so that minimum permeate flux $11.34 (L/m^2min.)$, was obtained for both of acid red and acid blue dye in TDS.

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