# ULTRAFILTRATION AS A CLEAN TECHNOLOGY FOR RECLAMATION AND REUSE OF WASTEWATER FROM TEXTILE INDUSTRY

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## ABSTRACT

The problem of color caused by dyehouse wastewater is one of important and unsolved environmental problems in Thailand. A traditional biological wastewater treatment process has been used widely but it still could not yield a satisfied treatment performance. Therefore, this research was done to know the feasibility for application of ultrafiltration as a clean technology for treatment and reclamation of dyehouse wastewater. Three kinds of wastewater were vat, disperse and direct dyehouse wastewater. The operating transmembrane pressure was in the range of 2.0-3.5 bars and feed pH was varied in the range of 3-10. The membrane used here was a flat-sheet type, made of regenerated cellulose acetate. It has a surface area of 0.0336 $m^2$. The composition of wastewater was prepared by the actual production formula of a textile factory. From the experimental results, the ultrafiltration membrane had the highest performance at operating pressure of 2 bars. When transmembrane pressure was higher than 2 bars,treatment efficiencies for all kinds of dyehouse wastewater decreased slightly. The removal efficiencies in terms of COD and TOC were higher than 80% at 2 bars, whereas the color was completely removed. Permeate fluxes were in the range of 40-70 $l/m^2$-h at transmembrane pressure of 2.0-3.5 bars. It was found that when feed pH was varied from 3 to 10, removal efficiencies in terms of COD and TOC were still higher than 80%. The color removal was completed. Therefore, ultrafiltration process is suitable for extensive pH range of the feed wastewater.

## 1. INTRODUCTION

Dyehouse wastewater has been recognized to have high color, pH and COD content since many chemicals have been used in the dyeing process. When the wastewater is discharged into the water source, the color in wastewater will affect the photosynthesis of the aquatic plants due to minimization of light penetration through the water. Also,most dyes are difficult to be biodegraded in the environment , then biological treatment of dyehouse wastewater together with domestic wastewater is not so successful. At present, the common treatment methods for dyehouse wastewater are either physico-chemical or biological treatments and both of them. The physico-chemical treatments which have been commonly used are chemical coagulation and chemical oxidation processes. In the case of biological treatment, the common method is activated sludge process. However, these methods still have some limitations on treatment efficiency. Therefore, wastewater discharged from textile industries cannot be treated efficiently. In this study, ultrafiltration process is an alternative method to know the feasibility to apply for dyehouse-wastewater treatment and reclamation. This process employs the pressure-driven force to separate the colloidal and high Molecular Weight Cut-Off (MWCO) molecules from the liquid mainly by sieving mechanism and some possible chemical interaction with membrane surface. Normally, ultrafiltration process have been used for separation of proteins and preparation of ultra-pure water. This reseach aims to propose the optimum operating conditions on decolorization and reclamation of dyehouse wastewater in order to design an ultrafiltration process as a clean technology for water and energy-saving in textile industry.

## 2. MATERIALS AND METHODS

### 2.1 Experimental set-up

The ultrafiltration system have been operated in a laboratory scale as shown in Fig.1. The dyehouse wastewater was pumped to the Mini-Lab 10 module having a size of 198 x 127 x 90 mm by a gear pump. The module contains four flat sheet- typed UF membranes. The membrane has MWCO of 10,000 and pore size of 0.002 micron. The surface area of the membrane is 0.0336 $m^2$. This UF membrane can tolerate high temperature upto 60 degree celcius. However, in this research, the feed temperature was kept under room temperature by a heat exchanger installed in the system.

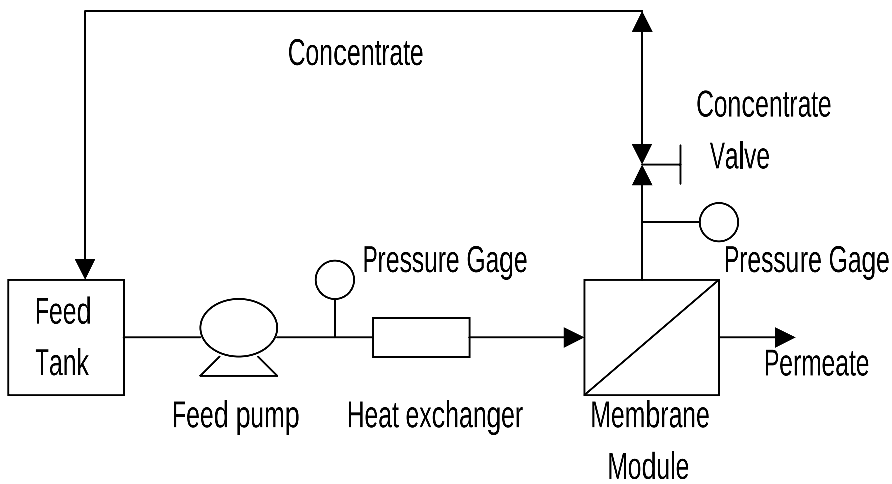


Fig.1 Experimental set-up for ultrafiltration system

### 2.2 Experimental method

*2.2 1 . Dyehouse-wastewater preparation*

The synthetic wastewater was prepared as an industrial-dyeing formula. The characteristics of dyehouse wastewater is shown in Table 1.

Table 1 Characteristics of dyehouse wastewater used in this research

| Dye | Color Tone | Commercial name | Color conc. (mg/l) | COD (mg/l) | TOC (mg/l) | Color unit (SU) | pH |
|---|---|---|---|---|---|---|---|
| Vat dye | Yellow | Indanthrene Yellow 5GF | 46 | 60-70 | 25-30 | 60-70 | 4-9 |
| | Red | Indanthrene Red FBB | 46 | 70-80 | 25-30 | 80-90 | 4-9 |
| | Blue | Indanthrene Blue RS | 46 | 70-80 | 30-35 | 60-80 | 4-9 |
| Disperse dye | Yellow | Disperse Yellow | 65 | 70-85 | 80-90 | 50-60 | 4-9 |
| | Red | Disperse Red | 65 | 80-85 | 80-90 | 70-80 | 4-9 |
| | Blue | Disperse Blue | 65 | 80-90 | 80-85 | 60-70 | 4-9 |
| Direct dye | Yellow | Best direct yellow-PGR | 88.2 | 100-110 | 20-30 | 140-150 | 4-9 |
| | Red | Sirius rubine K2BL | 88.2 | 40-45 | 20-25 | 190-200 | 4-9 |
| | Blue | Sirius blue KCFN | 88.2 | 60-70 | 30-40 | 300-400 | 4-9 |

*2.2.2 Ultrafiltration-system operation*

The operating transmembrane pressure was varied in the range from 2.0 to 3.5 bars to obtain the optimum transmembrane pressure. The feed pH was also adjusted to the range of 4-10 to know the feasibility on the application of the system in a wider range of feed pH. The permeate was collected every ten minutes until reaching the steady state condition.

*2.2.3 Analytical method*

Water quality obtained for the feed and the membrane-permeate, together with transmembrane pressure and flowrate were measured by the following methods as shown in Table 2.

Table 2 Parameters and analytical methods

| Parameter | Analytical Method |
|---|---|
| COD | Closed reflux |
| TOC | TOC measurement |
| Color | Spectrophotometer |
| pH | pH meter |
| Flowrate | Volume per time |
| Pressure | Pressure guage |

## 3. RESULTS AND DISCUSSION

### 3.1.Characteristics of ultrafiltration membrane

Membrane characteristic was initially investigated, employing the test with pure water passing through membrane to know the flux and resistance properties of the UF membrane before operating with dyehouse wastewater. The linear relationship between permeate flux , $J_w$ and transmembrane pressure, $\Delta P$ is shown in Fig. 2. The membrane resistance, $R_m$ can be obtained as functions of $J_w$, $\Delta P$, $\mu$ (viscosity) by equation (1)

$$R_m = \Delta P / (J_w * \mu) \qquad (1)$$

The membrane resistance obtained here is $2.0*10^{13}$ $m^{-1}$, and the permeate flux of this UF membrane is in the range of 20-100 $l/m^2/hr$ at the operating transmembrane pressure of 1.5-4.0 bars.

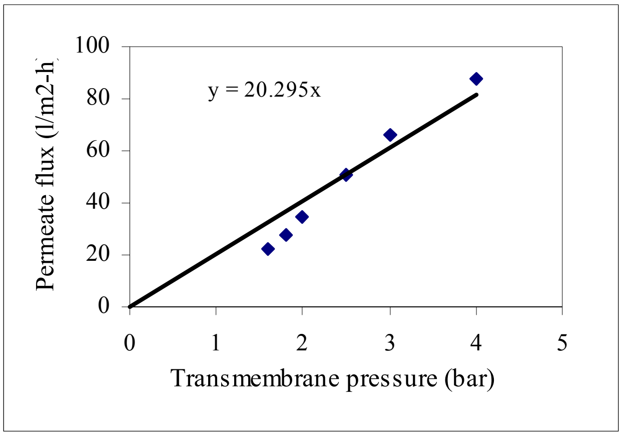


Fig.2 The relationship between permeate flux and transmembrane pressure for ultra-pure water

### 3.2 Effect of transmembrane pressure on dyehouse wastewater treatment with ultrafiltration membrane

*3.2.1 Effect of transmembrane pressure on permeate flux of three kinds of dyehouse wastewater*

The results obtained with three kinds of dyehouse wastewater are shown in Fig.3-a.,3-b.and 3-c. It was found that in the case of the same kind of dyehouse wastewater but different color tone, the permeate fluxes came out were indiffent. The filtration resistances (total resistance due to membrane resistance and the resistance from pollutant-accumulation on membrane surface) obtained in the case of vat dyehouse wastewater were $2.075*10^{13}$ $m^{-1}$, $2.076 *10^{13}$ $m^{-1}$ and $2.085*10^{13}$ $m^{-1}$ with yellow, red and blue tones,respectively; in the case of disperse dyehouse wastewater were $2.079*10^{13}$ $m^{-1}$, $2.121*10^{13}$ $m^{-1}$ and $2.152*10^{13}$ $m^{-1}$ with yellow, red and blue tones,respectively; in the case of direct dyehouse wastewaters were $2.368*10^{13}$ $m^{-1}$ ,$2.559 *10^{13}$ $m^{-1}$ and $2.583*10^{13}$ $m^{-1}$ with yellow, red and blue tones,respectively. The range of permeate fluxes at the operating pressure range from 2.0 to 3.5 bars were 40-70, 40-70 and 30-60 $l/m^2/hr$, in the case of vat, disperse and direct dyehouse wastewater, respectively.

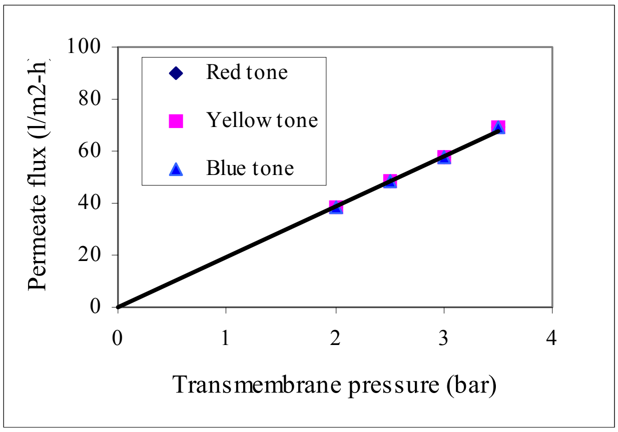


Fig.3-a Effect of transmembrane pressure on permeate flux for vat-dyehouse wastewater

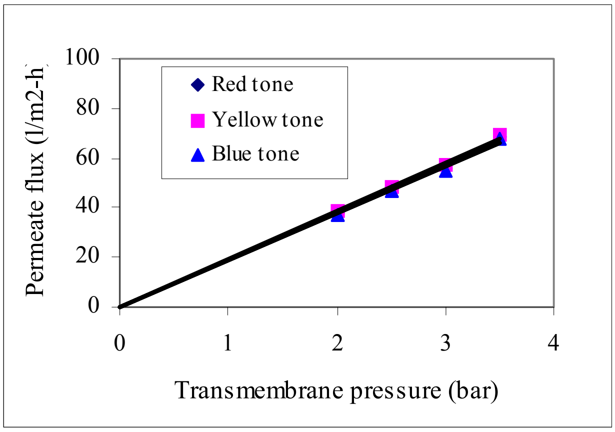


Fig.3-b Effect of transmembrane pressure on permeate flux for disperse-dyehouse wastewater

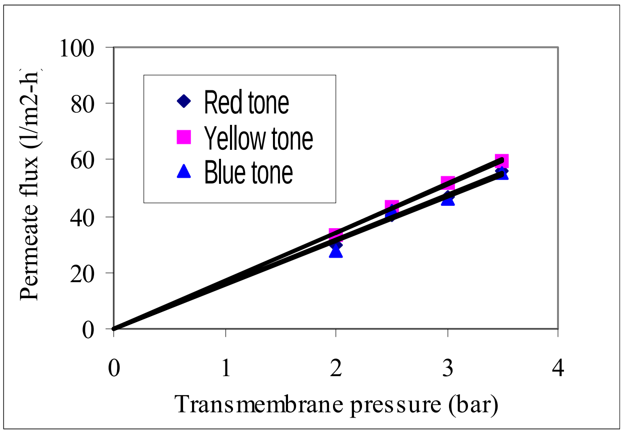


Fig.3-c Effect of transmembrane pressure on permeate flux for direct-dyehouse wastewater

*3.2.2 Effect of transmembrane pressure on dyehouse-wastewater treatment efficiency*

Table 3 shows that when the transmembrane pressure increased, treatment efficiency of dyehouse wastewater became decreased. It was found that the best treatment efficiency was at the operating pressure of 2 bars. The reason might be that an increase in pressure causes more leakage of organic compounds into the permeate. It is also shown from Table 3 that color removal efficiencies did not increase with increasing pressure for all kinds of dyehouse wastewater. Complete removal of color was obtained for vat and disperse dyehouse wastewater. However, in the case of direct dyehouse wastewater, color removal efficiency was in the range of 93-100%.

Table 3 Effect of transmembrane pressure on treatment efficiencies

| Dyehouse | % Removal | Yellow tone | | | | Red tone | | | | Blue tone | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Transmembrane pressure (bars) | | | | Transmembrane pressure (bars) | | | | Transmembrane pressure (bars) | | | |
| | | 3.5 | 3.0 | 2.5 | 2.0 | 3.5 | 3.0 | 2.5 | 2.0 | 3.5 | 3.0 | 2.5 | 2.0 |
| Vat dye | COD | 72 | 89 | 89 | 89 | 67 | 76 | 79 | 86 | 82 | 88 | 95 | 96 |
| | TOC | 79 | 83 | 87 | 88 | 78 | 84 | 85 | 86 | 82 | 83 | 90 | 91 |
| | Color | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Disperse dye | COD | 72 | 78 | 83 | 87 | 68 | 76 | 92 | 96 | 77 | 82 | 86 | 89 |
| | TOC | 91 | 94 | 95 | 95 | 93 | 93 | 94 | 95 | 94 | 93 | 94 | 96 |
| | Color | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Direct dye | COD | 81 | 88 | 87 | 96 | 57 | 74 | 57 | 100 | 93 | 93 | 100 | 100 |
| | TOC | 59 | 88 | 89 | 91 | 89 | 93 | 94 | 94 | 90 | 95 | 95 | 96 |
| | Color | 93 | 94 | 95 | 96 | 99 | 99 | 100 | 100 | 99 | 99 | 100 | 100 |

**3.3 Effect of feed pH on dyehouse-wastewater treatment efficiency**

Effect of pH on treatment efficiencies for vat, disperse and direct dyehouse wastewater is shown in Table 4. It was found that the feed pH in the range of 4-9 did not affect the treatment performance for the dyehouse wastewater as complete color removal could be obtained in the cases of vat and disperse dyehouse wastewater, and nearly complete color removal (higher than 96%) was achievable in the case of direct dyehouse wastewater. Therefore, ultrafiltration process can give high performance in terms of COD, TOC and color removal at the wide range of feed pH from 4 to 9.

Table 4 Effect of feed pH on treatment efficiencies

| Dyehouse | % Removal | Yellow tone | | | Red tone | | | Blue tone | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | pH 4 | pH 7 | pH 9 | pH 4 | pH 7 | pH 9 | pH 4 | pH 7 | pH 9 |
| Vat dye | COD | 100 | 89 | 79 | 96 | 86 | 96 | 95 | 96 | 79 |
| | TOC | 71 | 88 | 85 | 70 | 86 | 85 | 65 | 91 | 91 |
| | Color | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Disperse dye | COD | 89 | 87 | 92 | 87 | 96 | 92 | 88 | 89 | 85 |
| | TOC | 90 | 95 | 88 | 89 | 95 | 87 | 93 | 96 | 86 |
| | Color | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Direct dye | COD | 93 | 96 | 90 | 100 | 100 | 92 | 100 | 100 | 96 |
| | TOC | 65 | 91 | 86 | 76 | 94 | 62 | 88 | 96 | 79 |
| | Color | 97 | 96 | 96 | 99 | 100 | 100 | 100 | 100 | 100 |

### 3.4 Effect of particle size of dye on treatment efficiency

The particle sizes of dyes were measured by the dynamic light-scattering technique. The effects of particle sizes of vat dyes and disperse dyes on COD, TOC and color removal are shown in Figs. 4 and 5, respectively. It was found that the difference in particle size of dyes seemed to have insignificant effect on color removal in the case of disperse and vat dyes. The mechanism of this ultrafiltration membrane mainly seems to be a sieving mechanism since disperse and vat dyes have much larger sizes (approximately 100 times) than the pore-size of the membrane (only 0.002 micron). In the case of direct dye, the measurement of its particle size could not be achieved by the above technique since this kind of dye is easily soluble, however, it was still be filterable by the ultrafiltration membrane since almost complete removal could be achieved for color.

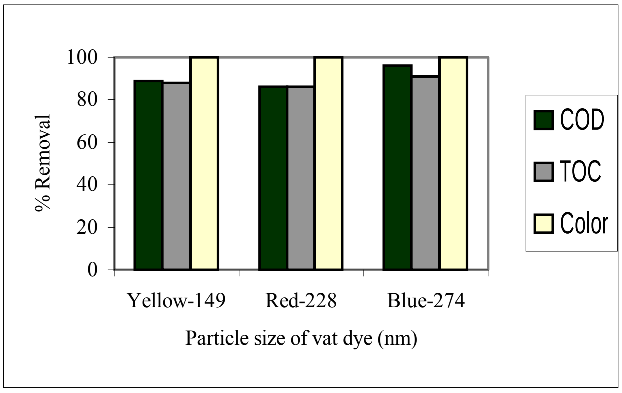


Fig.4 Effect of particle size of vat-dye on COD, TOC and color removal efficiencies

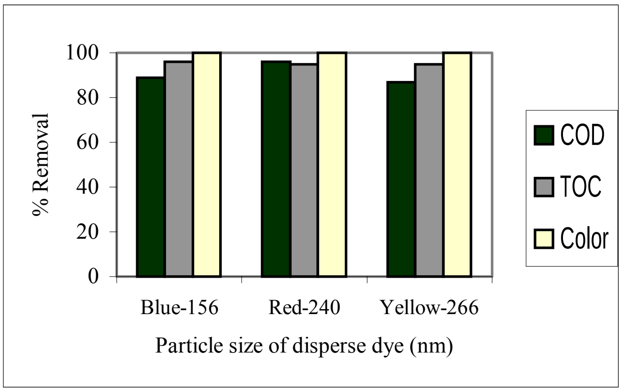


Fig.5 Effect of particle size of disperse-dye on
COD, TOC and color removal efficiencies

## 3. CONCLUSION

1. The optimum operating transmembrane-pressure for treatment of dyehouse wastewater was at 2 bars, and the obtained permeate flux was in the range of 30-40 $l/m^2$-h.
2. This ultrafiltration process can be applied for treatment and reclamation of dyehouse wastewater at a wide range of pH (4-9) very well since nearly complete color removal and more than 80% of COD and TOC removal could be achieved.
3. From this research, ultrafiltration process can be an alternative for treatment and reclamation of dyehouse wastewater in order to solve the problem of water scarcity for industrial sectors.

## 4. REFERENCES

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