## CHAPTER III

# INVESTIGATION OF COLOR REMOVAL FROM DAIRY INDUSTRY WASTE WATER USING NF270 MEMBRANE*

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## 1.Introduction

In dairy industry technology, water is used throughout all steps including cleaning, sanitization, heating, cooling, and floor washing, generating large volumes of effluents which are mostly white waters. Dairy wastewater has high biochemical oxygen demand (BOI) and chemical oxygen demand (COD) contents, high levels of dissolved or suspended solids including fats, oils, and grease, nutrients such as ammonia or minerals and phosphates, milk components like lactose and proteins, and cleaning chemicals and detergents. Therefore, it must be treated by appropriate methods before being discharged (Kertész et al., 2015; Formentini-Schmitt et al., 2013). In case of insufficient treatment, dyes in the wastewater cause the formation of color and toxic substances in the receiving environment. Although color poses an aesthetic problem at first glance, it prevents photosynthesis by decreasing the light transmittance in natural waters when it reaches high levels (Çapar, 2004).

Various membrane processes have been proposed for dairy wastewater treatment to produce purified water for water reuse or recover nutrients (Ivnitsky et al. 2005; Boussu et al. 2007). Unlike conventional methods, membrane technology is tolerant to variable levels of pollutants in the upstream and is four times smaller than conventional wastewater treatment plant (Bae et al. 2003). Membrane technology, which is known to be environmental friendIy, has ease of construction and control, low consumption of energy, no requirement of chemical

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substances to be added and is feasible for recovery of valuable metals (Licínio et al., 2015).

One-stage experiments such as ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) used in dairy wastewater treatment were investigated (Gong et al. 2012, Sarkar et al. 2006, Frappart et al. 2008). Among these membrane methods, nanofiltration uses membranes with very small pores (<1 nm) and requires operating pressures in the 10-50 bars range (Gherasim and Mikulášek 2014). There are two ways to operate nanofiltration process. While in dead-end filtration, all of the solution is directed towards the membrane area under applied pressure, in cross-flow filtration entire solution is directed parallel to the membrane surface (Tsibranska and Tylkowski 2013). The cross-flow is rather low to reduce concentration polarization and fouling as much as possible suitable (Koyuncu et al., 2018; Scott, 1995).

Nanofiltration process (NF) is used as a intermediate process of reverse osmosis and ultrafiltration which has advantages such as the effectiveness in removing the dissolved solutes, including multivalent ions and organic components with high molar mass with lower pressure requirements and higher fluxes than reverse osmosis. Studies indicate that NF is an effective process for secondary and tertiary treatment of wastewater in order to generate water for industrial, agricultural and indirect drinking reuse. However, evaluating the optimal operating conditions for each NF system allows inhancing the overall process performance, both in terms of permeation quality and fouling control quality (Andrade et al. 2014).

In this study, color removal from dairy industry wastewater was investigated by nanofiltration method. In order to determine the effect of filtration pressure (10, 15 and 20 bars) and feed temperature (25°C and 35°C) on color removal, dairy waste water was passed through NF270 membrane.

## 2. Materials and Methods

In this study, thin film composite nanofiltration membrane NF270 was tested. NF270 is a flat sheet type membrane and the effective filtration area of this flat sheet membrane is 150 $cm^2$. The properties of the membrane is given in Table 1.

Waste water used in this study was provided from the dairy industry in Eskişehir. The waste water obtained from the factory was taken the day before the experimental work was started and stored in the refrigerator in the laboratory to ensure that the properties of the waste water did not change. Table 2. shows the characteristics of the raw wastewater collected from a dairy plant.

Table 1. Properties of NF270 Membrane (Anonymous, 2020)

| Membrane | NF270 |
|---|---|
| Type | Organics Removal, Softening |
| pH Range | 2-11 |
| $MgSO_4$ Rejection | 99,2% |
| Pore size/MWCO | 200-400 Da |
| Flux (GFD)/psi | 72-98/130 |
| Polymer | Polyamide-TFC |

Table 2. Properties of Wastewaters Used in Experimental Study

| Parameters | Dairy wastewater |
|---|---|
| Max. Absorbance (nm) | 320 |
| $A_0$ (nm) | 0.184 |
| Conductivity (µs/cm) | 1384 |
| pH | 6.90 |
| COD (mg/L) | 561 |
| TSS (mg/L) | 55 |

Sterlitech-SEPA CF cross-flow nanofiltration system was used in the experimental study. A schematic representation of the system is given in Figure 1. The cross-flow membrane filtration system was operated for 120 minutes for each pressure value of 10, 15 and 20 bar pressures for the treatment of collected dairy wastewater. The experiments were repeated at 25°C and 35°C. This system consists of a membrane module, feed tank, pressure pump, scales, flowmeter, computer, thermostat and necessary fasteners. The effective area of the membrane in the system is 150 $cm^2$ (Kavak, 2017a, Kavak, 2017b). Temperature control is provided by WiseCircu heater in the system. This heater is used to keep the waste water in the supply tank at the desired temperature levels. During each experiment, samples were taken from the permeate into UV cuvettes for 5, 15, 30, 45, 60, 90 and 120 minutes of filtration time. Color was analyzed using the Hach Lange DR 3900 UV-vis spectrophotometer at the λmax value of 320 nm.

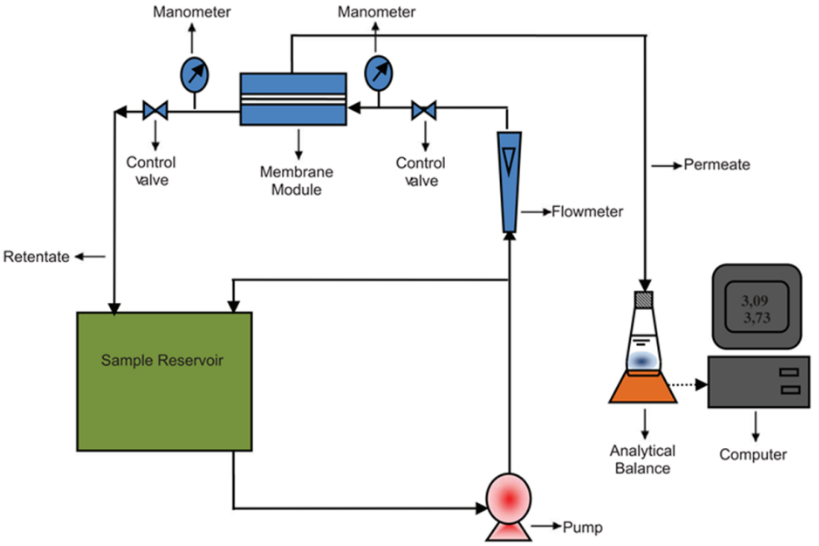



Figure 1: Schematic Diagram of the Cross-Flow NF Experimental Set Up.

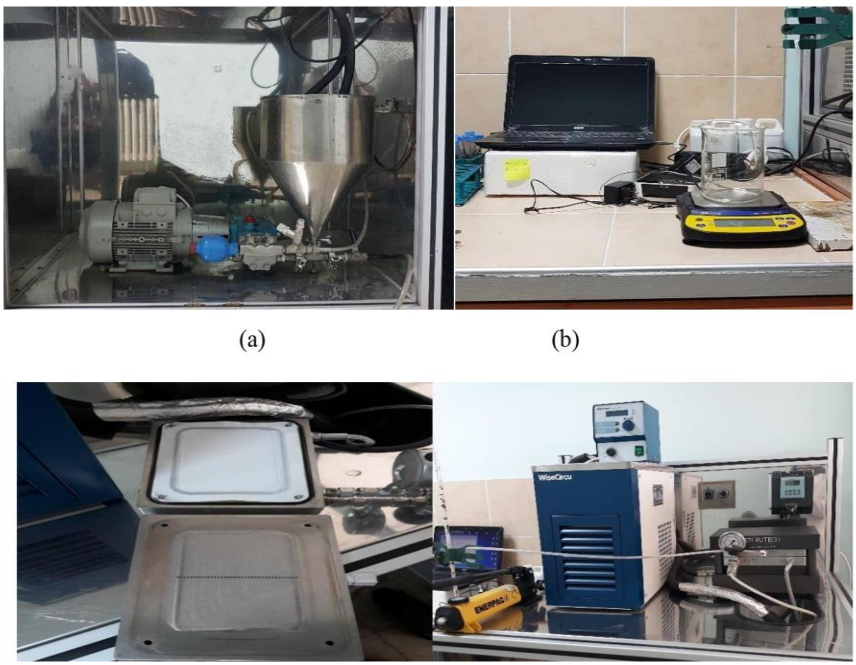


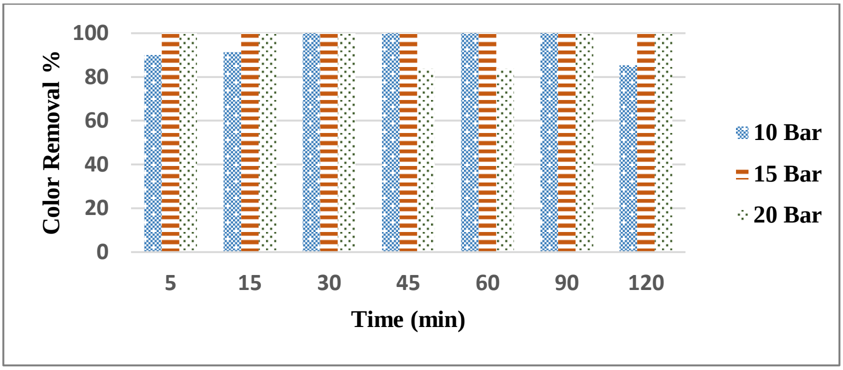

Figure 2: Cross Flow Membrane Filtration System

Color removal efficiency ($E_F$, %) was calculated by Eq. (1) based on the concentrations of a determined species in the permeate ($C_P$, mg/L) and in the feeding ($C_F$, mg/L).

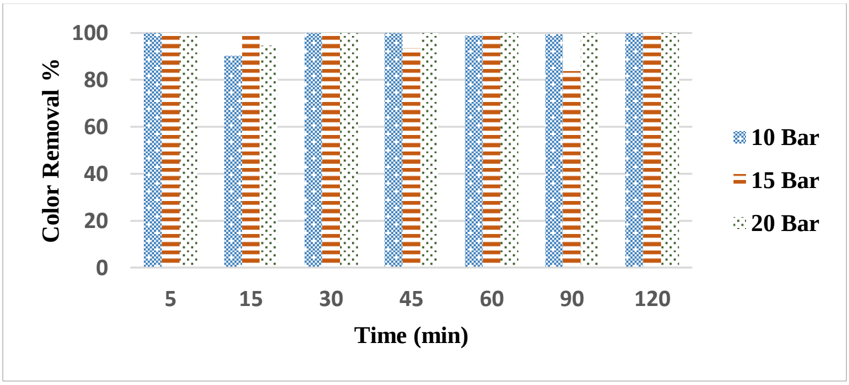
$$E_F = \frac{C_F - C_P}{C_F} \times 100 \quad (1)$$

### 3. Results and Discussion

The color removal performance of the NF270 membrane is shown in Fig.3. Very high percentage of color rejections were observed at all pressure and temperature values. At the end of 120 minutes color removal percentages were obtained as 85.3%, 100% and 100% for 10, 15 and 20 bar pressures at 25ºC temperature, respectively. At 35ºC temperature; color removal percentages were obtained as 100% for 10,15 and 20 bar pressures.




(a)




(b)

Figure 3: Color removal efficiencies of NF270 at pressures of 10, 15 and 20 bar for (a) 25°C and (b) 35°C

As can be seen from Fig. 3, At 25 ºC; color removal increases with an increase in membrane pressure at the end of 120 minutes. The maximum color removal was obtained as 100% for 15 and 20 bar pressures.

At 10 bar; as the feed temperature was increased from 25ºC to 35ºC at the end of 120 minutes, the color removal increased from 85.3% to 100%, respectively. At 15 and 20 bar; with the increase of temperature, the color removal of NF270 membrane did not change. At 35ºC, increasing pressure did not affect color rejection. Very high color removals were obtained under low pressure conditions. This result is very positive in terms of energy efficiency.

Ong et al. (2012) studied the decolorization and salt reduction of dyeing solution treated by NF270 and NF90 membranes. With respect to color removal, it is found that NF270 demonstrated greater stability in maintaining its separation efficiency (between 94 and 98% rejection) regardless of the feed properties and number of operation cycles (Ong et al., 2012).

## 4. Conclusions

In this study, performance of a NF270 membrane has been studied to treatment of dairy industry wastewater by cross-flow NF at different operating conditions. Effects of operating pressure and feed temperature were investigated on color removal. NF270 membrane used under different operating conditions of temperature and pressure showed high color removal efficiency. At the end of 120 minutes, the decolorization efficiency of NF270 membrane varied between 85.3-100%. The maximum color removal was obtained as 100% at 25ºC and 35ºC after 120 min of NF. According to the experimental results, NF270 membrane is efficient for color removal dairy industry wastewater.

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