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Extended Abstract

Studying Transmembrane Pressure, pH and Anionic Surfactant (SDS) Concentration Effects on MEUF Process Performance in Dairy Waste Water Treatment Using Response Surface Methodology Design

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Abstract
Surfactants are widely used to improve membrane processes due to their ability to trap toxic, organic compounds and heavy metals in industrial wastewater treatment. In this study, the micellar-enhanced ultrafiltration process (MEUF) was used to improve the efficiency of ultrafiltration process to reduce COD, TDS, and turbidity and promote membrane permeate flux in dairy wastewater treatment. The influence of three operating parameters: SDS concentration, transmembrane pressure and pH with their interactions effects were evaluated using surface response methodology (RSM) in box-behnken design. The results showed that the concentration of anionic surface active agent as one of the most influential factors due to the formation of concentration polarization layer and increase in the number of micelles had a negative effect on flux, but had a positive effect on the elimination of the contamination indexes. Also, due to the compression of micelles, the amount of pollutant removal was reduced at high operational pressures. In addition, increasing pH improved the removal of COD, TDS, and turbidity.

Keywords: Dairy waste water, Enhnaced Ultrafiltrasion, Micelle, Response Surface Methodology, Surface Active Agents

Introduction
Ultrafiltration is one of the membrane process used to separate the various compounds from the solutions. For example, this method is used to isolate macromolecules such as proteins from low molecular weight solvents. The UF process depends on the physical properties of the membrane, such as permeability, thickness and operational parameters such as feed type and concentration, transmembrane pressure, flow velocity on the membrane surface and temperature (Crites & Tchobanoglous, 1998). Micellar enhanced ultrafiltration process (MEUF) is a membrane separation method that improves the performance of the ultrafiltration by forming micelles from surface active agents (Puasa, Ruzitah, & Sharifah, 2011). The main

principle of separation in this process is that the surfactant monomers aggregate in the micelle form in critical micelle concentration (CMC). The size of the diameter of the micelles will be larger than diameter of membrane pores. Therefore, the compounds and particles that are trapped in micelle and monomers will be blocked by the membrane and will not pass through it. The unique feature of the MEUF process is that it can simultaneously create high separation efficiency as the reverse osmosis process and high permeability flux as the ultrafiltration process, so this process can be considered as a step to overcome intrinsic constraints, the process of reverse osmosis and nanofiltration process (Landaburu-Aguirre, 2012; Puasa *et al*., 2011). In this paper, dairy wastewater treatment was performed using ultrafiltration process and anionic surfactant as its enhancer and the effect of effective parameters on MEUF performance was also investigated.

Material and methods

Operation method

For each experiment's run, the surface active agent was first weighed and mixed in 100 mL of distilled water for 15 min with a magnetic stirrer at 300 rpm. The solution was then added to 8 liters of wastewater and stirred for 15 min. Finally, by adjusting the pH to the desired level, it was poured into the feed tank of the pilot. The membrane pressure was also regulated using the input and output valves on the modulus. A thermostat was used to adjust the temperature. After the flux was stable, permeate flow was analyzed (Hakimzadeh, Mousavi, Elahi, & Razavi, 2017).

Analyzed methods

The treated wastewater samples were evaluated for each of the pollutants as COD, TDS and turbidity after each experiment's run. In order to determine the turbidity of samples, the AL250T model of turbidometer aquatic ecosystem, made in Germany, was used. To determine soluble solids, the Ap-2000 model of TDS-meter was used by Akvarejad Company and the spectrophotometric method was used to determine the chemical oxygen demand (COD). The following equation was used to calculate the percentage of material discharged by the membrane under different operating conditions (Huang, Zeng, Qu, & Zhang, 2007):

$$R(\%) = \left(1 - \frac{C_p}{C_f}\right) \times 100 \qquad (1)$$

Where: the expression C_f is the concentration of pollutants in the feed and C_p is the concentration of pollutants in mg/lit in the flow.

Statistical analysis

The experiments were designed based on three levels of pressure, three levels of SDS concentration and three levels of pH using the Desing expert (version 7) software, using the surface response and in the box-behnken mode (Bezerra, Santelli, Oliveira, Villar, & Escaleira, 2008; Talebpour, Ghassempour, Abbaci, & Aboul-Enein, 2009).

Results and discussion

The results obtained from the experiments are presented for each of the responses in Table (1) (at levels below 5%). The accuracy of the quadratic model was also evaluated by analysis of variance.

Table 1. Linear, square, and reciprocal coefficients in turbidity, flux, TDS and COD models

Response	D_0	D_1	D_2	D_3	D_{11}	D_{22}	D_{33}	D_{12}	D_{13}	D_{23}	R^2
COD	39.76	3.61	1.30	0.81	0	0	0	-0.58	0	-0.25	0.96
TDS	25.54	-3.27	0.83	-0.45	0	0	0	-0.56	0	-0.24	0.97
Flux	53.33	-2.03	-1.51	-0.45	0	0	0	+0.35	0	-0.10	0.98
Turbidity	98.08	0.16	0.01	-0.05	0	0	0	-0.03	0	+0.01	0.97

The results showed that the effect of all variables had an incremental effect on the rejection of turbidity. Increasing the difference in pressure, surfactant concentration and pH also increased the percentage of TDS rejection. Probably, at low pH, H^+ ions compete with cations to absorb micelles. The COD removal rate increases with increasing surface active agent concentration in each pressure level. This behavior is due to the fact that the probability of formation of micelles in a layer near the surface of the membrane increases due to the phenomenon of polarization of the concentration. On the other hand, by increasing the pressure difference, due to the increase of the transmission of pollutant particles from the membrane, the percentage of COD rejection decreases. Increasing the pH and alkalizing the solution increases the COD rejection. This is due to the fact that the effects of acidity on the coagulant substance depend on the reactions produced in different pH conditions. When alkaline conditions prevail in the environment, larger and heavier clusters are created, resulting in higher removal efficiency. As it can be seen, there was a decrease in the permeate flux at the very beginning of the operation (by increasing the concentration of surfactant in all pressure levels), indicating that severe fouling occurs by increasing the concentration of surfactant. Different researchers have argued that by increasing the concentration of surfactant, the permeate flux decreases due to the accumulation of active surface factors and the formation of a micelles layer on the membrane surface. Also, the reduction of flux in low concentrations of surfactant (below the CMC) is due to the surface absorption phenomenon and the interference between the charged components with the opposite charge in membrane (Bade & Lee, 2011; El-Abbassi, Khayet, & Hafidi, 2011; Hakimzadeh *et al*., 2017; Rahmanian, Pakizeh, & Maskooki, 2010; Sikder, 2003).

Conclusion

The results showed that the effect of surfactant concentrations on turbidity increased with increasing concentration, which was about 1% and had linear effect in all three factors. Surfactants had a significant effect on COD removal, but the slope of this effect decreased with increasing pressure. There was also such a result for the amount of TDS rejection. The concentration of surfactant and pH had a decreasing effect, but increased pressure showed an increasing effect on the permeate flux. Finally, in view of the results of the desirable ability to separate COD and TDS from dairy wastewater, it is possible to find out the usefulness of the MEUF process in the treatment of these effluents. Certainly, due to the higher flux of this process rather than the NF process at transmembrane pressure, it is hoped that the MEUF process would replace costly processes such as NF and RO.

Extended Abstract

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