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Treatment of restaurant wastewater using ultrafiltration and nanofiltration membranes

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ABSTRACT

In this work, two commercial ultrafiltration (UF) membranes, i.e. UF PES-10 kDa and UF PVDF-100 kDa and two nanofiltration (NF) membranes, i.e. NF-90 and NF-270 were used to treat restaurant wastewater discharged from local medium-sized restaurant which served typical Malay halal foods. The wastewater which was subject to membrane treatment process was collected at the point of discharge without undergoing any pre-treatment process. The separation performances of membranes were characterized with respect to BOD_5, COD, turbidity and conductivity removal while the membrane sustainability was evaluated based on the water flux recovery. Promising results of COD and turbidity removal (between 97.8 and 99.9%) were able to achieve regardless of membrane type, indicating the size of pollutants contributing to COD and turbidity values are significantly larger than 100 kDa. Removal rates of BOD_5 and conductivity were found to be strongly dependent on the membrane pore size. As NF-90 exhibited the smallest pore structure among the membranes studied, it showed the highest BOD_5 (86.8%) and conductivity removal (82.3%). In terms of sustainability, it is found that the original water flux of NF-90 was able to be retrieved by >50% compared to between 15 and 38% reported in the UF membranes, after only a simple rinsing process. This indicated that NF-90 is less susceptible to fouling and is more suitable and reliable to be employed for restaurant wastewater treatment.

1. Introduction

Over the past thirty years, membrane-based separation process has emerged as one of the most promising techniques in the water and wastewater treatment field owing to the significant evolution of the membrane technology [1,2]. However, the potential of membrane as treatment process has not been examined for all types of wastewaters. For instance, the exploration of using membrane for restaurant wastewater is paid little attention and this can be reflected by the limited number of technical papers available in the literature [3,4].

Restaurant wastewater is water that has been used for cleaning meats and vegetables, washing dishes and cooking utensils, or cleaning the floor. The effluent is usually heavily loaded with organic matters from the leftovers of food and soup which are made of oily flavorings such as soy sauce, seasoning, spice, etc. Unlike most of the developed countries where the restaurant effluent is discharged into foul sewers leading to public sewage treatment plants, the effluent produced by local restaurant is mostly discharged into storm drains without proper on-site treatment process. This situation gets even worse with the lack of awareness by the general public in particular restaurant owner of the wastewater management issues. Furthermore, the presence of oil and grease in the wastewater also tends to foul the storm drain and generates unpleasant odor.

Although aerobic and/or anaerobic treatment of restaurant wastewater has been proposed in removing oil and grease from wastewater, the reactor size and operation cost make the process unacceptable for most small city restaurants [5]. Chemical coagulation on the other hand is found to be low efficiency in removing light and finely dispersed oil particles and possible contamination of foods by chemicals [6]. It is also reported that the removal efficiencies of electrocoagulation and electroflotation processes for oil and grease and suspended solids are not very high under the general operating conditions, making them unable to produce effluent that meets the acceptable level especially when the daily average influent COD of wastewater are too high [7]. In view of this, it is realized that membrane technology is very potential to overcome the limitations encountered by the above-mentioned treatment processes, owing to the several major advantages such as superior pollutant removal, consistent effluent

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quality, more compact footprint and often much simpler operation [8,9]. Moreover, no chemicals addition is required and the power consumption is very low, due to the low operating pressure applied (i.e. several bars) during treatment process.

The main objective of this work is to study the efficiency of the membrane-based technology in removing major pollutants exist in the wastewater discharged by medium-sized restaurants serving typical Malay halal food for local people, particularly Muslim people. Four types of commercial available ultrafiltration (UF) and nanofiltration (NF) membranes were selected in this study to investigate their efficiencies in reducing the levels of effluent, in particular BOD_5 and COD so as the treated wastewater could comply with local discharge standard. It is expected that the outcomes of this work can provide instructive information on the potential of using membrane technology for restaurant wastewater treatment process in an effort to reduce the environmental impact and possibly to recycle the treated effluent for non-potable reuse in the restaurant.

2. Materials and methods

2.1. Local restaurant wastewater

Table 1 shows the characteristics (detected ranges) of raw restaurant effluents collected from two local medium-sized restaurants situated in Taman Universiti, Skudai district (coordinate: 1.53344° N 103.61678° E) at four different business hours, i.e. 0700, 1200, 1600 and 1800 h, together with the limits of effluent discharged. Both restaurants are halal, serving customers with traditional Malay foods. But, since the food served for breakfast, lunch and dinner are different; the wastewater composition is varied from time-to-time, even it is discharged by the same restaurant. In this study, the raw influent sample was collected at the point of discharge (i.e. entrance of the drain) without undergoing any treatment process. Effluents were produced either from the food preparation (e.g. vegetable/meat washing), leftovers of wastes (e.g. oily flavoring, beverages and soup) or cleaning activities (e.g. dish/utensil washing and kitchen floor cleaning). As can be seen from the table, the quality of the effluent with respect to pH, BOD_5 and COD failed to meet the local government discharge standard. The extremely high values of BOD_5 and COD of the restaurant effluent could be attributed to the bloody effluent resulted from chicken/beef washing as well as the oily flavoring such as soy sauce, seasoning and spice used in food preparation. Although turbidity and conductivity are not included in the regulation, it would be still interesting to include both parameters during sample analysis. It is mainly because both parameters are widely considered in many wastewater treatment processes.

Table 1
Typical local restaurant effluent characteristics and parameter limits of effluent (Standard B) of environmental quality (Sewage and Industrial Effluents) regulation 1978.

Parameter[a]	Restaurant		Limits of effluent ([b]Standard B)
	Zam-Zam Corner Restaurant	Nor Café	
pH	4.49–6.15	4.86–5.19	5.5–9.0
BOD_5 (mg/L)	816.17–1097.25	928.58–1076.50	50
COD (mg/L)	10,356.67–16,443.33	837.33–1574.67	100
Turbidity (NTU)	402.67–1208	865.67–1199.33	*N/A*
Conductivity (μS/m)	915.33–2830	6266.67–15,940	*N/A*

[a] The range of value shown is obtained from four different measurements at different periods.
[b] Standard B is the standard parameter limits discharge into all inland waters, except inland waters within catchment areas.

2.2. UF/NF membranes and filtration experiments

All membranes used in the UF and NF tests are commercially available membranes. Table 2 shows the information on the four commercial membranes used for the treatment of restaurant wastewater. All the filtration experiments were conducted in a self-stirred membrane permeation cell (Model: HP4750, STERLITECH™) under nitrogen atmosphere. During experiment, the cell which containing a circular-shape flat membrane (with 14.6 cm^2 effective area) was placed on a magnetic stirrer in which a Teflon-coated magnetic bar was fitted into the cell and stirred at constant rotation of 250 rpm, providing agitation to minimize concentration polarization effect during filtration. The temperature and pressure of the filtration experiments were controlled at 25 °C and 2–4 bar, respectively. The membrane water flux J (L/m^2 h) was calculated by dividing the permeate volume Q (L) by the product of effective membrane area A (m^2) and the sampling time t (h).

$$J = \frac{Q}{At} \quad (1)$$

The efficiencies of membrane in removing specific pollutants from restaurant wastewater R (%) were determined by dividing the difference between initial feed value C_f and permeate value C_p with initial feed value, as expressed in Eq. (2).

$$R = \left(1 - \frac{C_p}{C_f}\right) \times 100 \quad (2)$$

Unit used for each parameter, i.e. BOD_5, COD, turbidity and conductivity is mg/L, mg/L, NTU and μS/m, respectively.

In order to obtain the water flux recovery of the membrane, the fouled membrane after restaurant wastewater treatment experiments was rinsed by letting DI water flow thoroughly on the top surface of membrane for 15 min. Then, the pure water flux of the membrane was re-evaluated and compared with its initial water flux.

2.3. Analytical methods

Analysis on the COD concentration of the feed and permeate samples was performed using spectrophotometer (Model: DR5000, Hach) by following the procedures handbook provided. BOD_5 analysis was performed with the use of handheld optical dissolved oxygen meter (Model: ProODO, YSI Inc.). The removal efficiencies of the membranes for conductivity were determined using a bench conductivity meter (Model: 4520, Jenway). Characterization on the sample quality with respect to turbidity was conducted using a portable turbidimeter (Model: 2100Q, Hach).

Table 2
UF and NF membranes used in this work.

Membrane	Manufacturer	Polymer	Type
UF PES-10 kDa	Alfa Laval	Polyethersulfone	Tight UF
UF PVDF-100 kDa	Amfor Inc.	Polyvinylidene difluoride	Loose UF
NF-90	DOWFILMTEC™	Polyamide ([a]MPD-TMC)	NF
NF-270	DOWFILMTEC™	Polyamide ([b]PIP-TMC)	NF

[a] MPD-TMC – 1,3-phenylene diamine-benzenetricarbonyl trichloride.
[b] PIP-TMC – piperazine-benzenetricarbonyl trichloride.