SESSION

C

ITSF SEMINAR
ON SCIENCE AND TECHNOLOGY

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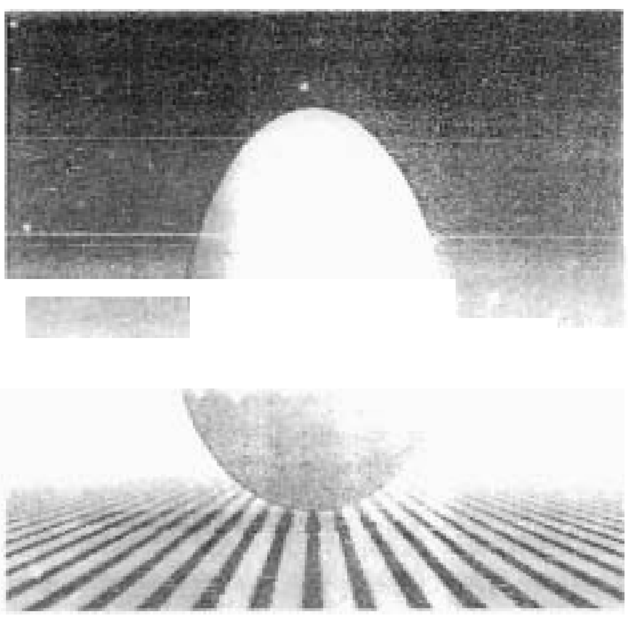
Indonesia Toray Science Foundation



Jakarta, 3 February 2003

Indonesia Room

JAKARTA SHANGRI-LA HOTEL

Kota BNI, Jl. Jendral Sudirman Kav. 1, Jakarta 10220

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Cross Flow Membrane Separation Of Algae in Agroindustrial Effluent Treatment Using Pond System. 2003

Penulis : Suprihatin, M. Romli, Andes Ismayana

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ITSF SEMINAR

ON SCIENCE AND TECHNOLOGY SCHEDULE

SCIENCE AND TECHNOLOGY RESEARCH GRANT PROGRAM 2001
INDONESIA TORAY SCIENCE FOUNDATION

Monday, February 3, 2003
SHANGRI-LA HOTEL JAKARTA

SESSION C

08.30 - 09.00	**OPENING CEREMONY**		
	SESSION 1	**MODERATOR**	**: Dr. Ir. Suprihatin, Dipl-Ing**
09.00 - 09.45	I	SPEAKER	: Leenawati Limantara, M.Sc. Ph.D
09.45 - 10.30	II	SPEAKER	: Dr. Ir. Izarul Machdar, M.Eng
10.30 - 11.00	**BREAK**		
	SESSION 2	**MODERATOR**	**: Leenawati Limantara, M.Sc. Ph.D**
11.00 - 11.45	III	SPEAKER	: Dr.rer.nat. Karna Wijaya, M.Eng
11.45 - 12.30	IV	SPEAKER	: Dra. Mariana Wahyudi, M.Si
12.30 - 13.30	**LUNCH**		
	SESSION 3	**MODERATOR**	**: Dr.rer.nat. Karna Wijaya, M.Eng**
13.30 - 14.15	V	SPEAKER	: Wellyzar Sjamsuridzal, Ph.D
14.15 - 15.00	VI	SPEAKER	: Dra. Wega Trisunaryanti, MS, Ph.D
15.00 - 15.45	VII	SPEAKER	: Dr. Ir. Suprihatin, Dipl-Ing
15.45 - 16.15	**BREAK**		
16.15 - 16.45	**CLOSING**		

Cross Flow Membrane Separation of Algae in Agroindustrial Effluent Treatment Using Pond System

Suprihatin[1], Muhammad Romli[1], Andes Ismayana[1]

ABTSRACT

This paper describes experimental studies on feasibility of using crossflow microfiltration (MF) and ultrafiltration (UF) for separation of algae in agroindustrial effluent treatment using pond system. Wastewaters of rubber and tapicca industry were used as a model for the agroindustrial wastewater. Results indicated that the MF and UF membranes could be used for separation of algaeefectively. The achievable flux was depended on the characteristic of wastewater, membrane characteristics, and the operating condition (transmembrane pressure, crossflow velocity, and algal concentration). Fluxes of app. 150 - 200 L/m^2 hr could be achieved by using MF membrane at a relative low cross flow velocity of 1.7 m/s and transmembrane pressures of 1.1 bar. In this condition, UF membrane produced a flux of app. 100 – 130 L/m^2 hr. The observed rejections of color, turbidity, COD (chemical oxygen demand), nitrate, ammonium, and phosphate have been extremely good (generally more than 85 percent), so that high permeate quality could be produced. Referring to the measured water quality parameters, permeate met the Indonesian standards for direct discharge and even for clean water.

1. INTROCUCTION

The most agroindustries, i.e. rubber and tapioca industry, generate a considerable amount of highly polluted wastewater, which contributes to environmental degradation significantly. Simple stabilization ponds can provide solution to the wastewater treatment with low investment, operation, maintenance and energy costs (Suprihatin, 1989; Garcea et al, 2000; Shelef and Ozoz, 2000). The climatic and geographical conditions, i.e. intensity of sunlight, warm temperature and availability of land also support the application of the systems in Indonesia.

In pond systems, organic matters are oxidized by bacteria. Algae utilize then the products of aerobic oxidation (CO_2, NO_3^-, PO_4^{3-}) for the synthesis of algal cells using solar energy in a photosynthesis process. About 115 g of algal cells is produced from 1 g of phosphorous. The removal of nutrients (nitrogen and phosphorous) by algae in the pond system can therefore prevent eutrophication in the receiving water body.

On the other side, the aerobic bacteria utilize oxygen produced during the algal photosynthesis for oxidation of organic pollutants. The use of algae in the wastewater treatment system has therefore some benefits, such as high quality of effluent and high economical value of algae. The algal biomass contains some valuable materials, i.e. protein, fat, glycerol, pigments, enzyme, amino acids, antibiotics, and biological fertilizer.

One of the most important steps of the algal production is the separation of the algae. Algae are difficult to separate by conventional separation processes (sedimentation) because of the low density different between algae and water. An alternative process to separate the algae from its medium is membrane filtration. This process performance does not depend on the algal density. Furthermore, the technology make possible to reuse the treated wastewater and the nutrients contents (N, P). The membrane filtration of algae will produce a high quality permeate that may be reused, and algal biomass that contains some valuable components (Figure 1). This technology can therefore be considered as a sustainable technology for waste-

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wastewater treatment within the economical and technological capabilities of developing countries.

In this research work, the feasibility of using microfiltration (MF) and ultrafiltratiuon (UF) membranes for separation of algae in agroindustrial effluent treatment using pond system was investigated. The objective of this research work was to evaluate the performance of the membrane process (flux, rejection, and effluent quality) at different conditions. The investigated factors include characteristics of wastewater, membrane characteristics, transmembrane pressure, crossflow velocity, and algal concentration.

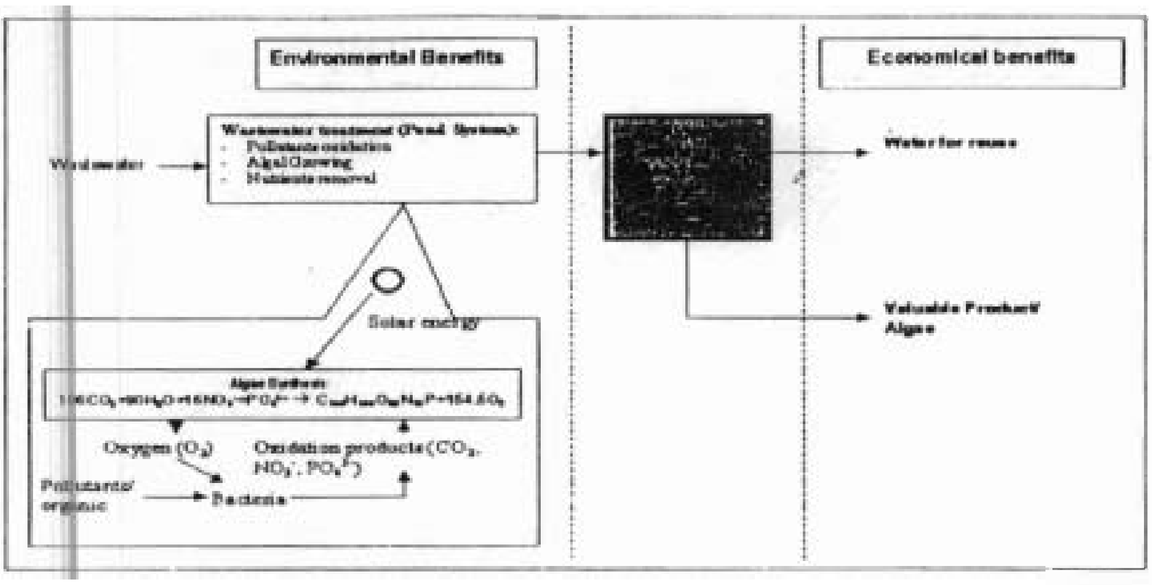

Figure 1. Environmental and economical benefits derived by membrane filtration for separation of algae in wastewater treatment system

2. MATERIAL AND METHODE

2.1. Membranes

Hydrophobic polysulfone microfiltration (MF) membrane with nominal pore size of 0.2 µm and surface modified PVDF (Polyvinilidine fluoride) ultrafiltration (UF) membrane with Molecular Weight Cut-Off (MWCO) of 10.000 Da were used for this experiments. Plate membranes with an effective area of 10.8 cm^2 were used for the experiments.

2.2. Algal suspensions

Wastewaters of tapioca industry and rubber industry were used for the growing the algae. Because of the low nitrogen concentration in the liquid waste of tapioca industry, an amount of 0.4 g/L urea was added as an external nitrogen source (Suprihatin, 1989).

The algae were cultivated in three boxes (50 x 50 x 30 cm^3) for each wastewater. The boxes were covered with transparent plastics to allow solar energy and prevent it from rainwater. After each experiment, the algal suspension was returned to the box, from which the suspension was taken. Clean water was added to the boxes regularly for replacing the evaporated water and maintaining the boxes volume constant.

2.3. Method

The separation of algae was conducted with principle of crossflow filtration in bench scale. The performance (flux, rejection, and permeate quality) of MF and UF membranes for separation of algae was determined at different operating conditions, including time, crossflow velocity (v), transmembrane pressure (Δp), and algal concentration or total suspended solids/TSS. Schematic diagram of crossflow filtration apparatus is shown Figure 2. The experiments were performed using a thin-cannel-type module having a channel depth of 5 mm. The experiments were conducted with three replications for each condition. A pump was installed for generating the flow of the suspension crossing the membrane surface. The algal suspension was circulated with a pump equipped with a by-pass to regulate the flow rate entering the module. The flux was measured every 15 minutes. Permeate of each run was collected for laboratory analysis. Because the permeate flow rate (app. 200 mL/run) was very low relative to medium volume (20 L), a constant suspension concentration was assumed. The laboratory analysis covered the following parameters: total suspended solids (algal concentration), turbidity, color, COD, ammonium, nitrate, and phosphate. The same parameters of the feed were measured to be able to determine the removal efficiency. The laboratory analysis of the parameters was conducted according to the Indonesia National Standard (SNI) for water and wastewater quality examination.

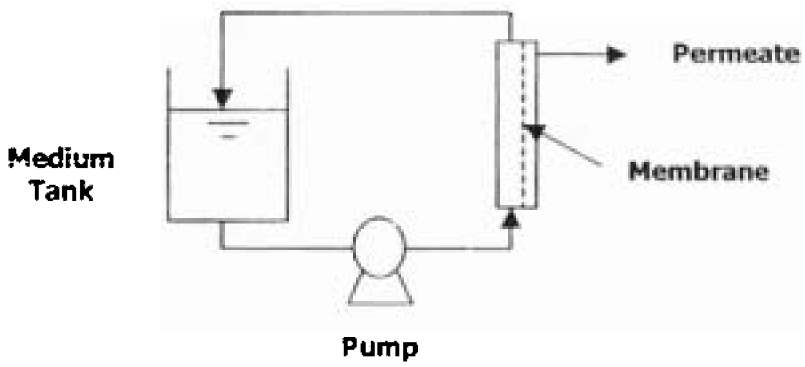

Figure 2. Schematic diagram of apparatus set up for crossflow filtration

3. RESULTS

It is not intention of this paper to present exhaustive records of experimental results, but rather than to summarize process performance and to discuss aspects of interest (flux, rejection, and permeate quality).

3.1. Flux

Figure 3 shows the changes in flux of MF and UF membranes during cross flow filtration of algae. The experiments were conducted with effluents of rubber and tapioca industry at a cross flow velocity (v) of 1.7 m/s, a transmembrane pressure (Δp) of 1.1 bar, an algal concentration of app. 1500 mg/L. The operating temperature was in the range of 29 and 31°C. Generally, the fluxes of the membranes decreased during the filtration time to reach an apparent steady-state value. In the case of wastewater of rubber industry, the quasi steady-state fluxes were app. 200 L/m^2 hr for the MF and app. 130 L/m^2 hr for the UF membrane. Lower fluxes were observed, if wastewater of tapioca industry was used as a medium for growing algae. In this case, the quasi steady-state fluxes were equal, namely 100 L/m^2 hr for both membranes. The initial flux at the beginning of the MF operation decreased faster than the flux of the UF membrane. Figure 3 demonstrates that the flux was not controlled by membrane resistance, presumably by resistance of deposition layer on and within the membrane. The membrane resistances have had no significant effect on the achievable flux, especially in the case of wastewater from tapioca industry

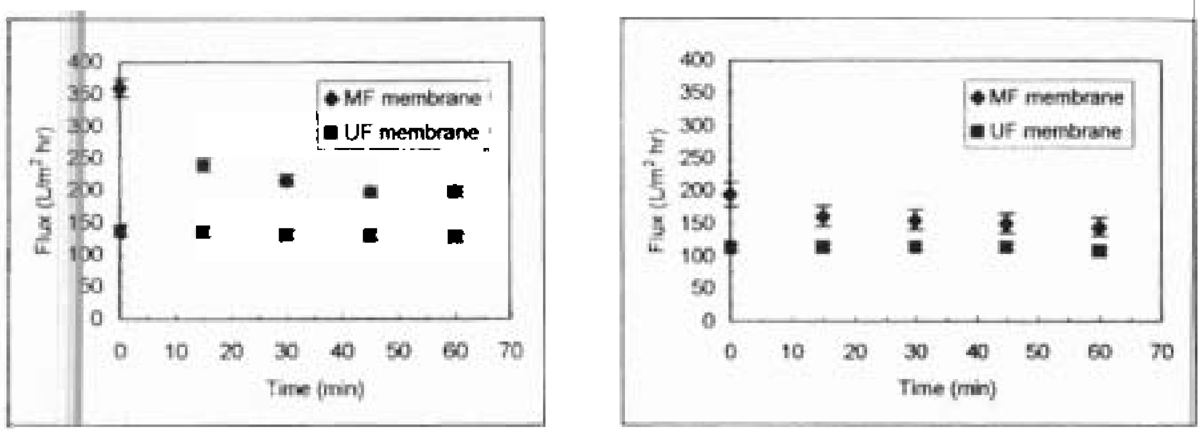

Figure 3. Flux of MF and UF membranes during the filtration of algae in effluents of rubber industry (left) and tapioca industry (right) at $\Delta p = 1.1$ bar, $v = 1.7$ m/s

Table 1 shows results of the experiments conducted at different characteristic of medium and membranes, transmembrane pressures, and crossflow velocity. The presented fluxes were fluxes at a filtration time of 60 min, where the fluxes were at the queasy steady state. At a low transmembrane pressure and a high crossflow velocity, the flux of the MF membrane tends to be higher than flux of UF membrane. However, with regard of the variation fluxes of MF and UF membranes were relative equal for both mediums at higher transmembrane pressures and lower crossflow velocity. This indicates that the resistance of the deposition layer on and within membrane determines the achievable fluxes of the membranes.

Table 1. Flux of MF and UF membranes at different conditions

Feed / Medium	Transmembrane pressure (bar)	Crossflow velocity (m/s)	Flux (L/m^2 hr)	
			MF	UF
Wastewater of rubber industry	1.1	1.7	197 ± 10	128 ± 6
	1.8	1.4	180 ± 5	155 ± 20
	2.8	0.9	148 ± 10	170 ± 10
Wastewater of tapioca industry	1.1	1.7	144 ± 16	107 ± 5
	1.8	1.4	148 ± 10	170 ± 10
	2.8	0.9	113 ± 19	117 ± 8

Algal concentration plays an important rule in the cross flow filtration, because it influences the characteristics of the suspension. A series of experiments at different algal concentrations was carried out with rubber industry and tapioca industry wastewaters at transmembrane pressures of 1.1 – 2.8 bar and cross flow velocities of 0.9 – 1.7 m/s. The flux of MF membrane decreased as the algal concentration was increased (Figure 4). However, in the algal concentration range of 736 – 2476 mg/L the effect of algal concentration on the flux of MF membrane was not significantly.

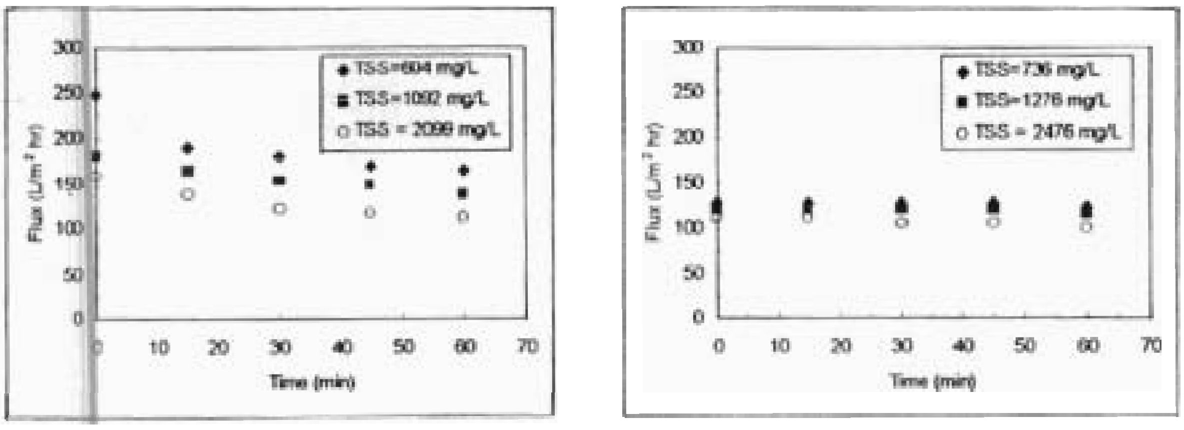

Figure 4. Flux of MF membrane (left) and UF membrane (right) as a function of filtration at different algal concentration (measured as TSS) at Δp = 1.1 bar, v = 1.7 m/s

3.2. Treatment Efficiency

Agroindustrial effluents contain soluble and suspended substances with a broad range of molecular size and molecular weight. Membranes have a certain cut-off related to the molecular size of the solutes, and the separation efficiency is therefore depending on the pore size of the membrane. This is demonstrated in Figure 5, where observed rejections of color, turbidity, COD, ammonium, nitrate, phosphate, and TSS are shown.

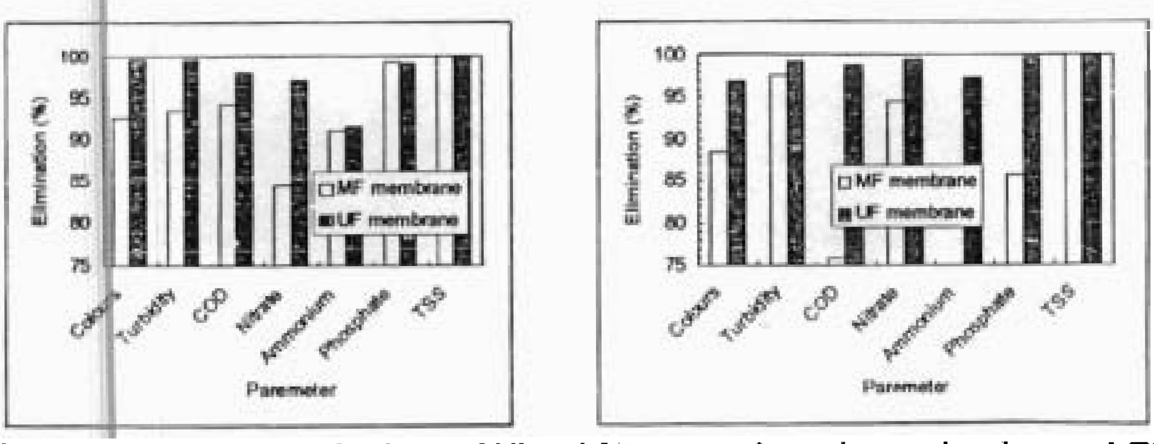

Figure 5. Rejections of color, turbidity, COD, ammonium, nitrate, phosphate and TSS from effluent of rubber industry (left) and tapioca industry (right) by MF and UF membranes Δp = 1.1 – 2.8 bar, v = 0.9 – 1.7 m/s

The observed rejections have been extremely good, and of particular interest is the apparent color and turbidity rejections of more than 90 percent. The high rejection results in clear permeate (see Figure 6). The high rejections (more than 85 percent) of soluble nutrients (ammonium, nitrate, and phosphate) by the MF and UF membranes are possibly because of complexing with proteinaceous material. The deposition on and within the membrane played an important role in the rejection of the soluble substances. Without the secondary layer, the soluble nutrients would pass the membrane because of their relative small size compared to the membrane pore size or MWCO. From the Figure 5, it appears that UF membrane gives higher rejections of the water quality parameters. The smaller the pore size or cut-off of the membrane, the higher the rejection will be. However, the deposition of particles (i.e. algal biomass) at the membrane surface form a secondary layer, which tends to reduce the membrane pore size and leads to increasing the rejection of soluble substances.

3.3. Permeate Quality

Table 2 shows the quality of permeate of MF and UF membranes for separation of algae. Appearance of permeates compared to the feed is shown in Figure 6. Referring to the measured water quality parameters, the produced permeate meets the Indonesia standards for direct discharge (Permenkes No. 416/MENKES/PER/IX/1990) and for the clean water (Kep. MENKLH No. 51/MENKLH/10/1995) and therefore can be considered as being acceptable for reuse or recycling.

Table 2. Permeate quality achieved by MF and UF membrane filtration

Parameter	Unit	Microfiltration (Δp = 1.1 – 2.8 bar, v = 0.9 – 1.7 m/s)		Ultrafiltration (Δp = 1.1 – 2.8 bar, v = 0.9 – 1.7 m/s)	
		Feed	Permeate	Feed	Permeate
Wastewater of Rubber Industry:					
Colors	PtCo	267 ± 19	19 ± 4	527 ± 7	2 ± 1
Turbidity	NTU	45.3 ± 8.5	2.9 ± 0.8	448.7 ± 3.5	1.6 ± 0.4
COD	mg/L	239 ± 5	14 ± 4	233 ± 56	4 ± 2
Nitrate	mg/L	1.49 ± 0.11	0.23 ± 0.02	4.78 ± 0.43	0.14 ± 0.08
Ammonium	mg/L	9.92 ± 0.89	0.88 ± 0.01	9.62 ± 0.08	0.81 ± 0.02
Phosphate	mg/L	1.60 ± 0.06	0.01 ± 0.00	0.56 ± 0.06	0.01 ± 0.00
TSS	mg/L	563 ± 3	0 ± 0	679 ± 7	0 ± 0
Wastewater of Tapioca Industry:					
Colors	PtCo	550	62.9 ± 12.8	550	17 ± 2
Turbidity	NTU	461	11.7 ± 2.3	461	2.9 ± 0.5
COD	mg/L	157 ± 35	38 ± 8	657 ± 177	8 ± 2
Nitrate	mg/L	6.79 ± 1.77	0.37 ± 0.07	21.82 ± 9.89	0.11 ± 0.03
Ammonium	mg/L	12.84 ± 0.03	3.51 ± 0.03	14.44 ± 0.88	0.39 ± 0.03
Phosphate	mg/L	2.91 ± 0.08	0.42 ± 0.02	3.63 ± 1.49	0.01 ± 0.00
TSS	mg/L	1135 ± 70	0 ± 0	2211 ± 183	0 ± 0

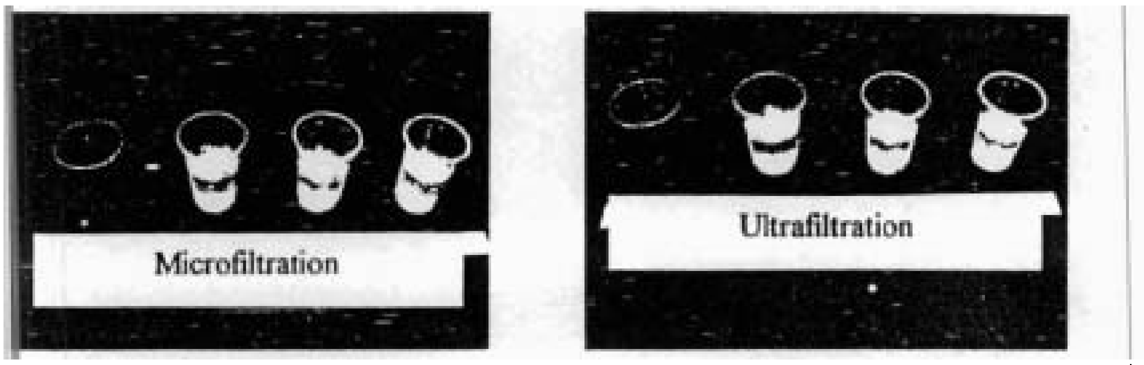

Figure 6. Appearance of feed and permeate of MF and UF membranes

4. CONCLUSION

Results of the experiments for separation of algae showed that MF and UF membranes could be used for complete separation of algae in agroindustrial effluents. The achievable flux was depended on the characteristic of wastewater, membrane characteristics, and the operating condition (transmembrane pressure, crossflow velocity, alga concentration). Fluxes of app. 150 - 200 L/m^2 hr could be achieved by using MF membrane at a relative low cross flow velocities of 1.7 m/s and transmembrane pressures of 1.1 bar. In this condition, UF membrane produced fluxes of app. 100 – 130 L/m^2 hr.

Both MF and UF membranes retained some important pollutants significantly. The observed rejections have been extremely good, and of particular interest is the apparent color and turbidity rejections of more than 90 percent. The high rejections (more than 85 percent) of soluble nutrients (ammonium, nitrate, and phosphate) are possibly because of complexing with proteinaceous material. The deposition of particles (i.e. algal biomass) on and within the membranes seems to contribute in reducing the membrane pore size and lead to increasing the rejection of soluble substances.

The permeate quality obtained from the experiments was very high. The measured water quality parameters met the requirements of the Indonesian standards for direct discharge and even for the clean water. The results indicate that reuse or recycle of the agroindustrial effluents is technically possible.

ACKNOWLADGMENTS

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