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## Effect of natural coagulant application on microfiltration performance in treatment of secondary oxidation pond effluent

S. Katayon\*, M.J. Megat Mohd Noor, W. Kien Tat, G. Abdul Halim, A.M. Thamer, Y. Badronisa

Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia  
Tel. +60 389466362; Fax +60 386567129; email: katayon@eng.upm.edu.my

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### Abstract

A secondary oxidation pond effluent was treated using hollow-fibre crossflow microfiltration and coagulation process. Preliminary tests were carried out to find the optimum dosage of *Moringa oleifera* (a natural coagulant) for the coagulation process. Optimum dosage of *Moringa oleifera* was recorded as 100 mg/L for turbidity of secondary oxidation pond effluents ranging between 30 and 100 NTU. Turbidity removal achieved ranged between 50 and 57%. The performance of microfiltration coupled with coagulation using optimum dosage of *Moringa oleifera* was investigated. Better flux performance and lower rate of fouling were achieved when combining microfiltration with coagulation. Pseudo-steady state flux of 3 L/m<sup>2</sup>.h at a relatively constant suction pressure of less than 0.6 bar was obtained after 300 h of filtration time. Results showed that the values of COD, BOD<sub>5</sub>, alkalinity, VSS, TS, turbidity and pH in the filtrate were not influenced significantly by incorporation of coagulation using *Moringa oleifera*. The filtrate quality of about 50 mg/L COD, 25 mg/L BOD<sub>5</sub>, 2 mg CaCO<sub>3</sub>/L alkalinity, 1 NTU turbidity, 1 mg/L TSS and VSS respectively was produced when using microfiltration with and without coagulation.

**Keywords:** *Moringa oleifera*; Oxidation pond effluent; Natural coagulant; Microfiltration; Coagulation

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\*Corresponding author.

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## 1. Introduction

Oxidation ponds represent 12% of all treatment plants in Malaysia. Most of the oxidation ponds are unable to treat wastewater efficiently to comply with the local standards. Therefore, integration of the process or a hybrid process in treating these effluents is a necessity. The most common hybrid processes are microfiltration–coagulation [1,2], membrane bioreactors [3–5], ultrafiltration–anaerobic primary sludge digestion [6] and microfiltration–flocculation [7].

The establishment of microfiltration–coagulation may shed light in treating secondary oxidation pond effluent in Malaysia. Previous researchers have applied the microfiltration–coagulation process for treating secondary oxidation pond effluent [1], anoxic waste stabilization pond effluent [8] and retention pond water [9]. However, previous studies have used chemical coagulants in their coagulation process.

Usage of natural coagulant such as *Moringa oleifera* is better than chemical coagulant since it is easily biodegradable, does not produce large volume of sludge and also does not pose hazard to the environment [10,11]. Moreover, sludge generated using *Moringa oleifera* as coagulant is less bulky compared to a chemical coagulant [12]. Ndabigengesere et al. [10] documented that the mechanism of coagulation with *Moringa oleifera* appeared to consist of adsorption and neutralization of the colloidal charges. Usage of *Moringa oleifera* as natural coagulant had been reported by other researchers [12–14].

Therefore, the objectives of this research are to design and fabricate a system for treating secondary oxidation pond effluent using microfiltration–coagulation process, in which *Moringa oleifera* is used as a coagulant agent.

## 2. Material and methods

### 2.1. System design

The model is comprised of a holding tank, an

aeration tank and an effluent tank. The coagulation is set to occur in the holding and aeration tanks while microfiltration only in the aeration tank. The schematic layout of the model is shown in Fig. 1.

A hydrophilic hollow-fibre membrane module supplied by Mitsubishi Corporation, with the characteristics presented in Table 1, was used.

### 2.2. Preparation of *Moringa oleifera* solution as coagulant

Dry *Moringa oleifera* seeds were collected around the vicinity of Taman Sri Serdang, Malaysia. The seeds coats and wings were removed and

Table 1  
Characteristics of hollow fibre membrane

Hollow fibre	Dimension
Length, cm	12
Inner diameter, mm	0.227
Outer diameter, mm	0.355
Available surface area, m <sup>2</sup>	0.1606
Pore size, μm	1–2.5

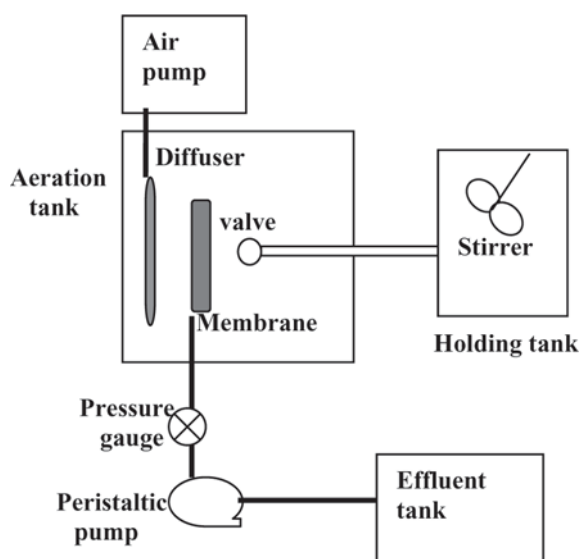


Fig. 1. Schematic diagram of the model.

the kernels dried in the oven for 24 h at 50°C. The kernels were ground to fine powder for 1 min to allow easy extraction of the active ingredient when soaked in water. Different series of concentrations were prepared from the stock solution (10,000 mg/L) by adding a certain volume of distilled water.

### 2.3. Collection of wastewater sample

Secondary oxidation pond effluent sample was collected at Serdang, Malaysia and characterized [15]. Results are presented in Table 2.

### 2.4. Jar test

The jar test was conducted to determine the effective dosage of *Moringa oleifera* in reducing the turbidity of the sample. Due to variation of the turbidity of the sample (30–100 NTU), the samples were categorized to a low-turbid sample (30–70 NTU) and a high-turbid sample (70–100 NTU). Different concentrations of *Moringa oleifera* (100–1200 mg/L) were tested on both samples. About 500 ml of low-turbid secondary oxidation pond effluent was put in the beaker and the tester was switched on at a speed of 100 rpm for rapid mixing. After 2 min, the speed was reduced to 40 rpm for slow mixing and this continued for 20 min for flocculation. One hour

settling time was allowed before the residual turbidity was measured.

### 2.5. System operation

Secondary oxidation pond effluent was fed into the holding tank at a mixing speed of 40 rpm. For a 30 L sample, 300 ml *Moringa oleifera* coagulant which corresponded to 100 mg/L as effective dosage was then added. The sample then flowed into the aeration tank by gravity. The sample volume in the aeration tank was controlled by means of a float valve. Three diffuser stones with 3.5 L/min air flowrate were then operated to provide aeration in the tank. The flow rate of peristaltic pump was fixed at 0.019 L/min.

Parameters including pH, flux, pressure, BOD<sub>5</sub>, COD, TS, VSS, turbidity and alkalinity were monitored. The operation of the system with coagulation was conducted for 52 d. For the first 36 d, the volume of the aeration tank was maintained at 25.5 L. The retention time was about 2.205 d (53 h). It was longer than the normal retention time of facultative oxidation ponds in Malaysia, which is 14 h. The retention time of the tank was then reduced to 16 d, and changes of the permeate quality were compared with the previous days. The effective volume of the aeration tank was further reduced to 13.5 L, giving even a shorter retention time of 28 h or 1.167 d.

Table 2  
Secondary oxidation pond effluent characteristics

Parameter	Range
Temperature, °C	27.5–29.9
pH	7.11–7.78
Dissolved oxygen, mg/L	4.00–6.15
Turbidity, NTU	29.5–106.0
BOD <sub>5</sub> , mg/L	45.5–191.0
COD, mg/L	64–240
Alkalinity, mg/L	160–240
TSS, mg/L	30–100
VSS, mg/L	22–92
TDS, mg/L	202–337
TS, mg/L	273–430

## 3. Results and discussion

### 3.1. Jar test

The optimum dosage of *Moringa oleifera* for both low and high turbid samples was 100 mg/L. Increasing the dosage of the coagulant did not help in improving the removal of turbidity, in fact this increased the residual turbidity of the coagulated sample. However, higher removal (50%) was achieved for the high-turbidity sample. This was in agreement with findings reported by Suleyman and Okuofu [16]. They documented the increase in turbidity removal with increasing the initial

turbidity of a sample. *Moringa oleifera* as a polyelectrolyte thus is not an effective coagulant for low-turbidity water because of the low rate of the interparticle contact. However, a higher dosage of the coagulant will lead to the increase of the residual turbidity. The large dose will eventually lead to the saturation of the polymer bridge sites and cause restabilization of particles due to an insufficient number of particles to form more interparticle bridges [16].

### 3.2. Variation of flux and pressure with time

As presented in Fig. 2, both microfiltration with coagulation and without coagulation showed high initial filtrate flux, which rapidly decreased within the first 100 h. However, it is clearly observed that microfiltration without coagulation had a steeper curve which indicates the faster rate of fouling. Pseudo-steady state flux for microfiltration with coagulation ( $3 \text{ L/m}^2\cdot\text{h}$ ) was found to be higher than microfiltration without coagulation ( $2 \text{ L/m}^2\cdot\text{h}$ ). Therefore, coagulation improved the efficiency of microfiltration from the aspect of fouling rate and consistency of the pseudo-state flux.

As shown in Fig. 3, the pressure of 0.6 bar was reached within less than 100 h for microfiltration without coagulation and 300 h for microfiltration with coagulation. The pressure was maintained at 0.6 bar throughout the study after 300 h for microfiltration with coagulation.

### 3.3. Variation of COD with time

Fig. 4a indicates a 60% COD reduction for a raw sample, which was mostly obtained by the microfiltration process alone. The COD value for the sample in the aeration tank was mostly lower than the raw sample. This is partly due to the oxidation process in the aeration tank, either chemically or biologically, which converted the biodegradable compounds in the raw sample to other vaporating compounds. A sudden increment of the COD value in the aeration tank at 1200 h is

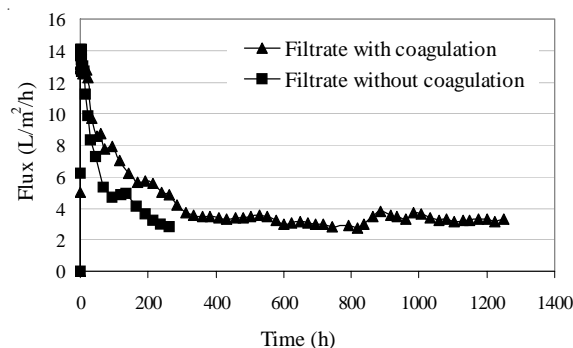


Fig. 2. Variation of filtrate flux with time during microfiltration with and without coagulation.

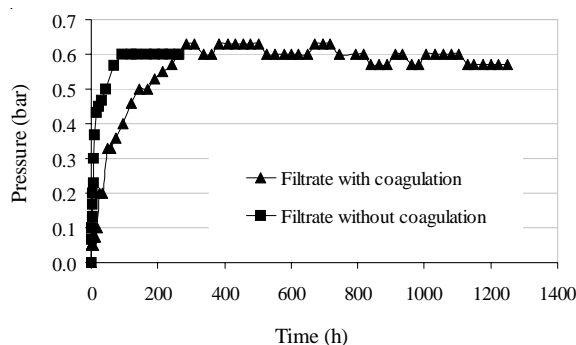


Fig. 3. Variation of filtrate pressure with time during microfiltration with and without coagulation.

attributed to the abundant presence of *Daphnia* sp. which act as a polishing agent in domestic wastewater and feed on settled flocs at the bottom of the aeration tank.

Fig. 4b shows the variation of COD with time for microfiltration without coagulation. The COD value of the filtrate is again found to be better than that of the sample in the aeration tank and the raw sample. The COD in the aeration tank as high as  $650 \text{ mg/L}$  and the average COD of  $150 \text{ mg/L}$  for the raw sample have been successfully reduced to less than  $50 \text{ mg/L}$  in the filtrate. Almost about 67% of COD from the raw samples was reduced. This strongly suggests that microfiltration alone can treat the raw sample to less than  $50 \text{ mg/L}$

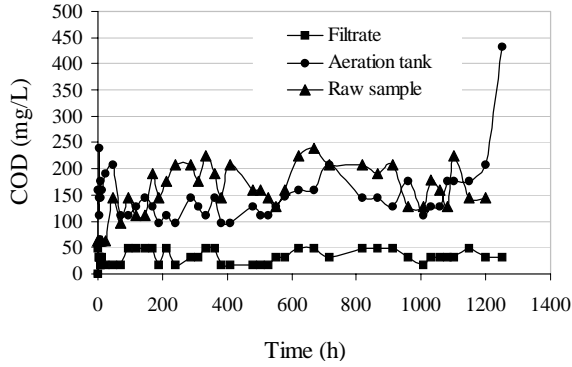


Fig. 4a. Variation of COD with time during micro filtration-coagulation.

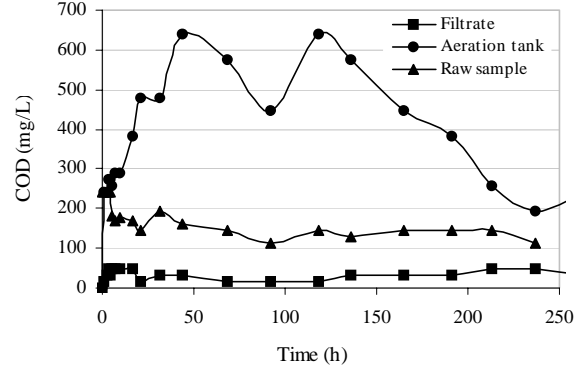


Fig. 4b. Variation of COD with time during microfiltration.

COD. Fluctuation of the COD value for the sample in the aeration tank is mostly due to the suspension of colloidal particles in the pond effluent.

### 3.4. Variation of alkalinity with time

Figs. 5a,b shows the variation of alkalinity with time for microfiltration with and without coagulation. Alkalinity of both the filtrate and the sample in the aeration tank was reduced by 99%.

One possibility is that acidic compound almost like humic acid is being produced by some zooplankton or *Daphnia* which is able to neutralize the alkalinity present in the wastewater. *Daphnia*

was firstly observed to appear in larger numbers in both microfiltration with and without coagulation after 200 h of filtration time.

### 3.5. Variation of BOD<sub>5</sub> with time

Figs. 6a,b show the variation of BOD<sub>5</sub> with time for microfiltration with and without coagulation, respectively. About 75% BOD<sub>5</sub> reduction was recorded from the raw sample in microfiltration with and without coagulation.

Sudden increment in BOD<sub>5</sub> for the sample in the aeration tank in microfiltration with coagulation was in line with the increment of COD.

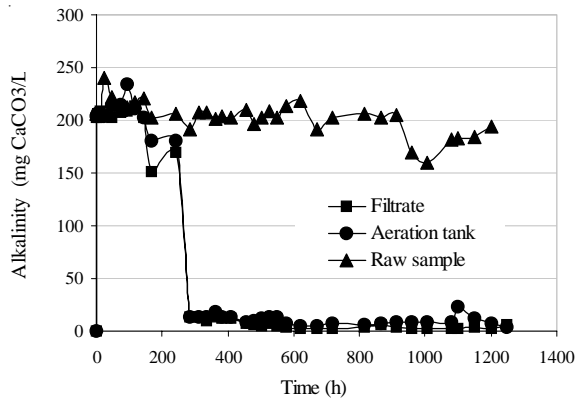


Fig. 5a. Variation of alkalinity with time during microfiltration-coagulation.

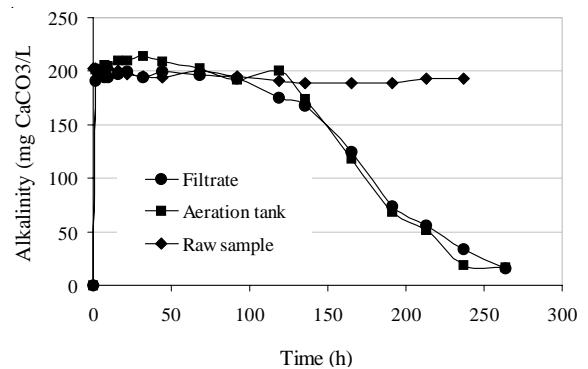


Fig. 5b. Variation of alkalinity with time during microfiltration.

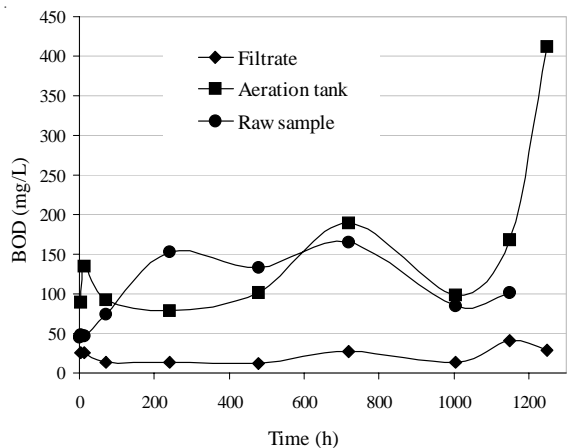


Fig. 6a. Variation of BOD with time during microfiltration-coagulation.

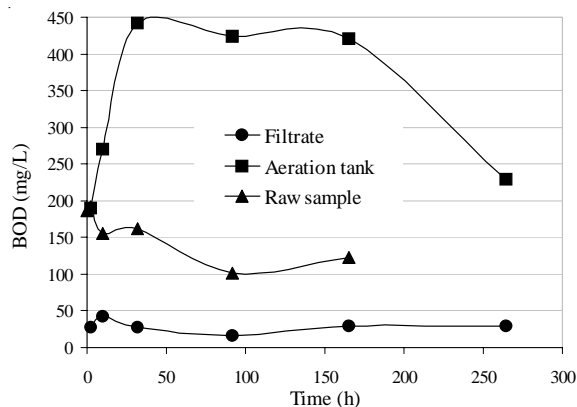


Fig. 6b. Variation of BOD with time during microfiltration.

Fluctuation of BOD<sub>5</sub> for the sample in the aeration tank in the case of microfiltration without coagulation was due to suspension of colloidal particles.

### 3.6. Variation of VSS with time

Figs. 7a,b show the variation of VSS with time for microfiltration with and without coagulation, respectively. About 99% reduction for VSS was observed for both microfiltration with and without coagulation. The increase in VSS towards the end of the study was probably due to the increment in the turbidity for the sample in the aeration tank.

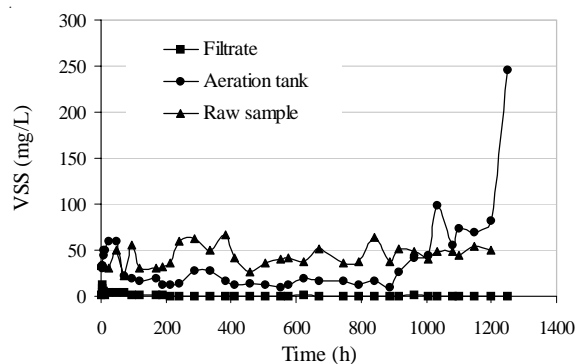


Fig. 7a. Variation of VSS with time during microfiltration-coagulation.

### 3.7. Variation of TS with time

Fig. 8a,b show the variation of TS with time for microfiltration with coagulation and without coagulation. Generally, TS in the filtrate and the sample in the aeration tank is slightly higher than in the raw sample for the case of microfiltration with coagulation. In contrast, a huge difference of TS is observed between the filtrate, the sample in the aeration tank and the raw sample for microfiltration without coagulation. High TS value which is found in the sample in the aeration tank is mainly due to high TSS and high TDS. Lower

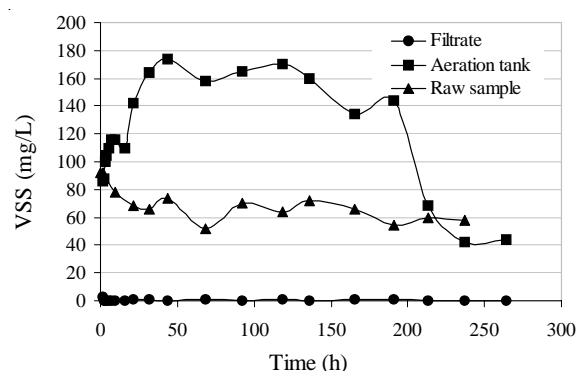


Fig. 7b. Variation of VSS with time during microfiltration.

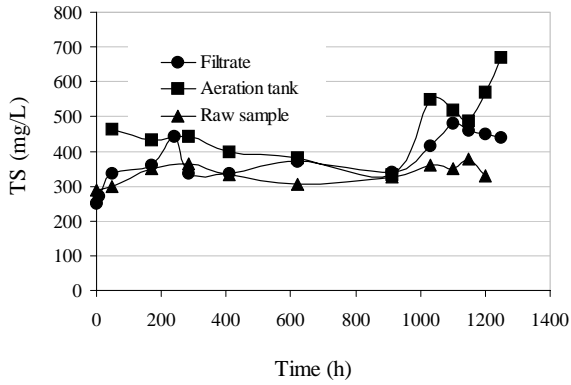


Fig. 8a. Variation of TS with time after microfiltration-coagulation.

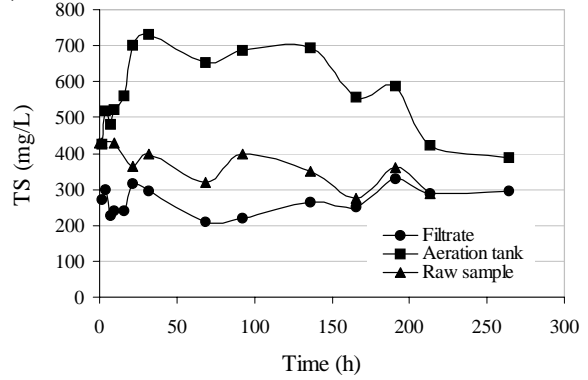


Fig.8b. Variation of TS with time after microfiltration.

TS value in the filtrate is mostly attributed to a low TSS which has been retained by the membrane.

3.8. Variation of pH with time

Figs. 9a,b indicate a decrease in pH after 150 h of filtration. Between 0–150 h of filtration, the filtrate and the sample in the aeration tank became more alkaline. This could be due to conversion of some compounds readily present in the pond effluent into alkaline compounds by the aeration process. However, as more samples being added, the aeration process could not provide enough

oxygen throughout the whole tank. Therefore, this created an anoxic condition in some pockets in the tank and as a result, acidic substances in turn were produced.

3.9. Variation of turbidity with time

The variation of turbidity with time during microfiltration with and without coagulation is presented in Figs. 10a,b. In both cases, residual turbidity for the filtrate was recorded at less than 1 NTU. This accounted for 99% removal of turbidity from the average value of 70 NTU for the raw sample.

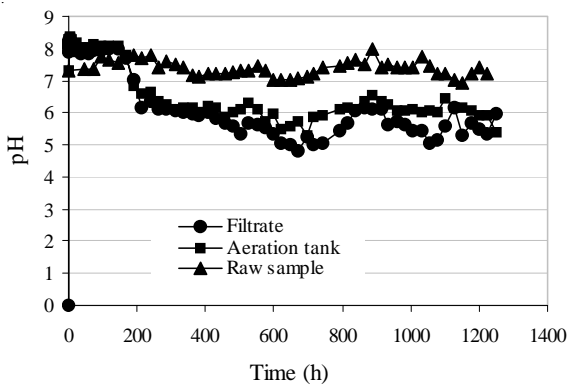


Fig. 9a. Variation of pH with time during microfiltration-coagulation.

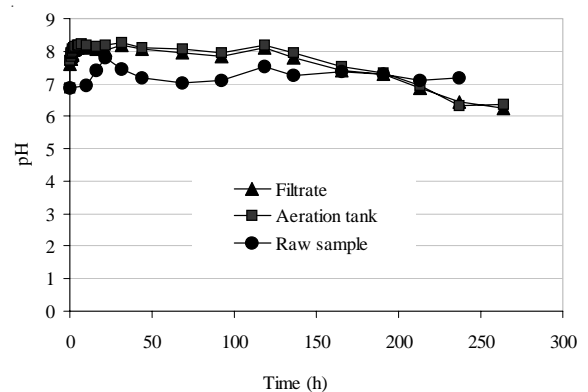


Fig. 9b. Variation of pH with time during microfiltration.

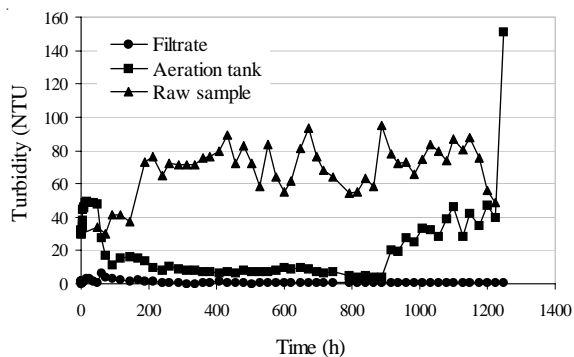


Fig. 10a. Variation of turbidity with time during microfiltration–coagulation.

As shown in Figs. 10a,b regardless of any value of turbidity for the raw sample, final turbidity for the treated sample always was below 1 NTU. This also indicated that microfiltration alone able to treat high turbid secondary oxidation pond effluent. Turbidity of the sample in aeration tank for microfiltration with coagulation remained 10 NTU during 100–900 h of filtration time and increased suddenly to maximum value of 150 NTU. This might attributed to the coagulated particles which slowly combine and settle at the bottom of the tank regardless of the mixing condition. Therefore, the surface water of the tank only contained fine particles. However, the existence of *Daphnia* and other protozoa such as *Euglena* and rotifer in larger numbers towards the end of study enabled them to feed on the settleable flocs and this resuspended the flocs up to the surface of the tank.

#### 4. Conclusion

Better flux performance and lower rate of fouling were achieved when combining microfiltration with coagulation. Pseudo-state flux at 3 L/m<sup>2</sup>.h and constant pressure not exceeding 0.6 bar were obtained after 300 hT of filtration time. The values of COD, BOD, alkalinity, VSS, TS, and pH in the filtrate were not influenced by incorporation of coagulation using *Moringa oleifera*. Hollow-fibre

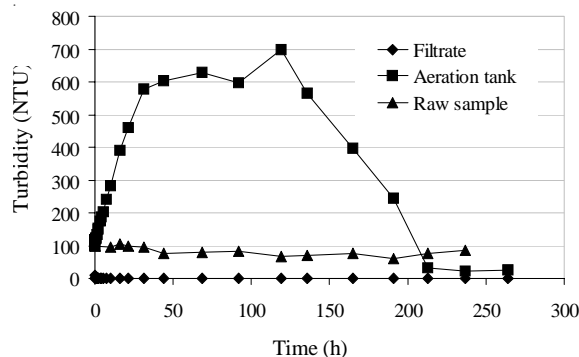


Fig. 10b. Variation of turbidity with time during microfiltration.

crossflow microfiltration plays a major role in treating secondary oxidation pond effluent. However, coupling of microfiltration and coagulation definitely enhances and prolongs the life of the membrane. The filtrate with the quality lower than 50 mg/L COD, 25 mg/L BOD<sub>5</sub>, 2 mg CaCO<sub>3</sub>/L alkalinity, 1 NTU turbidity, 1 mg/L TSS and VSS respectively was produced with both microfiltration with and without coagulation.

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