Membrane bioreactor for leachate treatment

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Abstract

Solid waste that is improperly handled will be a source of pollution to land, air, surface water and groundwater besides creating an odor problem. In this study, a membrane bioreactor (MBR) was utilized as a treatment system for a synthetic leachate that used a microfiltration hollow fibre membrane. The performance of the MBR and the membrane itself were monitored which mainly focused on organic matters and heavy metal removal for lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) in the synthetic leachate. The MBR was operated at different backwash interval time i.e. 15, 30 and 60 minutes. This experiment found that the COD removal efficiency was up to 98%. The average heavy metals removal was 94%, 92%, 42% and 75 % for Pb, Cd, Cu and Zn respectively.

Keywords: Leachate, MBR, heavy metal, backwash

1.0 Introduction

The development of membrane technology has opened a new era of wastewater treatment. The coupling of a membrane with bioreactor has increased interest in this area of studies. Membrane bioreactor (MBR) is defined by combining membrane technology with biological reactors for the treatment of wastewater [1]. The leachate produced by landfills contains a high concentration of organic compounds which also includes significant inorganic matters including heavy metals [2]. The variation of the composition is due to the differences in waste composition and landfill technology. Heavy metals would account for a certain portion of the toxicity of the leachate and landfill leachate is still one of the major sources of heavy metals discharged to the surrounding environment [3]. Heavy metals in leachate can be particularly dangerous because of the movement through soils is mainly related to the fluid dynamics and to the sorption on the solid phase [4]. The aim of this study is to investigate the performance of MBR for simultaneous organic and heavy metal removal from leachate. A few parameters were chosen to monitor the performance of the treatment efficiency and the characterization of the leachate. The parameters involved are chemical oxygen demand (COD), suspended solid (SS), pH and and mainly focus on heavy metals such as cadmium (Cd), copper (Cu), zinc (Zn) and lead (Pb).

2.0 Materials and method

The schematic diagram of the bench-scale MBR is as shown in Figure 1. The system basically consists of three tanks of the same dimensions. The volume occupied for each tank is 15 liter. Two pumps are used as feed pump and suction pump. A microfiltration hollow fibre membrane was immersed in the aeration tank. The specifications of the membrane are as shown in Table 1. The membrane module was connected to the suction pump whereby it can be used in reversible condition. Hence, it can be used for backwashing process.

Air was supplied through the vacuum pump to each tank and helps to keep the contents in suspension and it will help to prevent the biofilm from getting thicker on the membrane by producing a shear stress on the surface of the membrane. The air valve in every tank is used to let the air pass through into the bioreactor tank. This will help the MBR to operate at aerobic condition or anaerobic condition. However, in this study the aerobic condition is the major concern.

Table 1
Specifications of the hollow fibre membrane

Membrane Type	Microfiltration
Pore Size (μm)	0.4
Surface Area (m^2)	0.2
Configuration	Hollow fibre
Material	Polyethelene
Manufacturer	Mitsubishi Rayon (Japan)

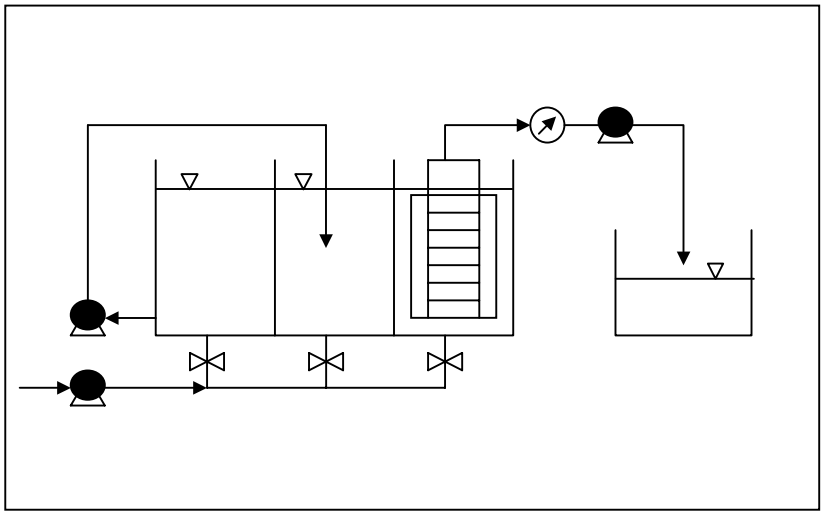

Figure 1: Experimental setup for synthetic leachate treatment

2.1. Feed and Seeding

The seed sludge used for inoculating MBR was collected from the other experiment of excess sludge in the laboratory of Environmental Engineering, UTM. The domestic wastewater collected from the oxidation pond of the Universiti Teknologi Malaysia, Skudai and Taman Sri Pulai, Skudai was used as substrate feeding. During the start-up period, the COD of the wastewater of the sludge was 2800 mg/l with MLSS of about 1600 mg/l. The seeding period takes about three weeks until a good activated sludge was observed. The synthetic leachate (feed) was prepared using the recipe of synthetic leachate as adapted from [5]. It was prepared for 5 liter for every new batch of experiment and placed into the feed tank. Thus, the composition of the synthetic leachate for 5 litre solution is shown as in Table 2.

Table 2
Composition of synthetic leachate of 5 liter solution

Composition	Weight (g)
Glucose	4
Lab Lemco	0.4
NH_4HCO_3	0.4
KH_2PO_4	0.4

(Adapted from Ujang, 1990)

200 ml of solution of heavy metal traces were prepared. The concentration of the heavy metal is representing the heavy metal content in MSW incinerator (MSWI) ash which was adapted from [6]. Then, 2 ml of every tracer metals was added into the 5 liter of synthetic solution. The composition of heavy metals is shown as in Table 3.

Table 3
Composition of heavy metals for 200 ml of solution

Composition	Concentration (g/l)
Lead	2.5
Cadmium	5
Copper	1.25
Zinc	60

2.2. Operating Conditions

The experimental investigation in this study is mainly focused on the performance of the MBR. The aeration rate of the bioreactor tank was 6.5 l min^{-1} with flux rate range from 6.5-12 l m^{-2} h^{-1}. Backwash process was done for every new batch of feed. The permeate was used in the backwashing process because the suction pump can work reversibly. The effect of the backwash period was also being monitored. A series of experiments were conducted at three different backwash interval time i.e. 15, 30 and 60 minutes. For the 15 minutes operation, the experiment was running for 15 minutes and the backwashing process will utilize the same duration as the operation. The experiment was monitored for 8 hours in a day. The flux reading was taken every 5 minutes while during the backwash period whereby the permeate was reutilized in

the backwashing process. The similar procedure was repeated for the duration of 30 minutes and 60 minutes of operation mode. Table 4 simplifies the operating conditions for this series of experiments.

Table 4
Operating conditions of MBR

Parameters	Operating conditions		
Loading (liter)	5		
HRT (d)	1.7		
Influent flow rate, Q (m^3/d)	$1.5x10^{-3}$ (constant)		
Air flow rate (l/min)	6.5		
Cleaning method	Permeate backwash		
Operation mode	15:15	30:30	60:60
Backwash frequency	16	8	4
Operation time (h)	8	8	8

3.0 Results and discussions

Figure 2 shows the flux value at different operation mode. The result obtained shows that the flux values decrease with the increasing of time. However, at mode operation of 30 minutes, flux obtained is relatively high compared to 15 and 60 minutes operation. Generally, the membrane fouling will occur at any operation mode. Normally, the backwash process for hollow fibre membrane taken place at every 15 minutes after 15 minutes of filtration [7] using the air sparging technique. Since the permeate was used in the experiment as backwashing media, thus it will affect the membrane performance.

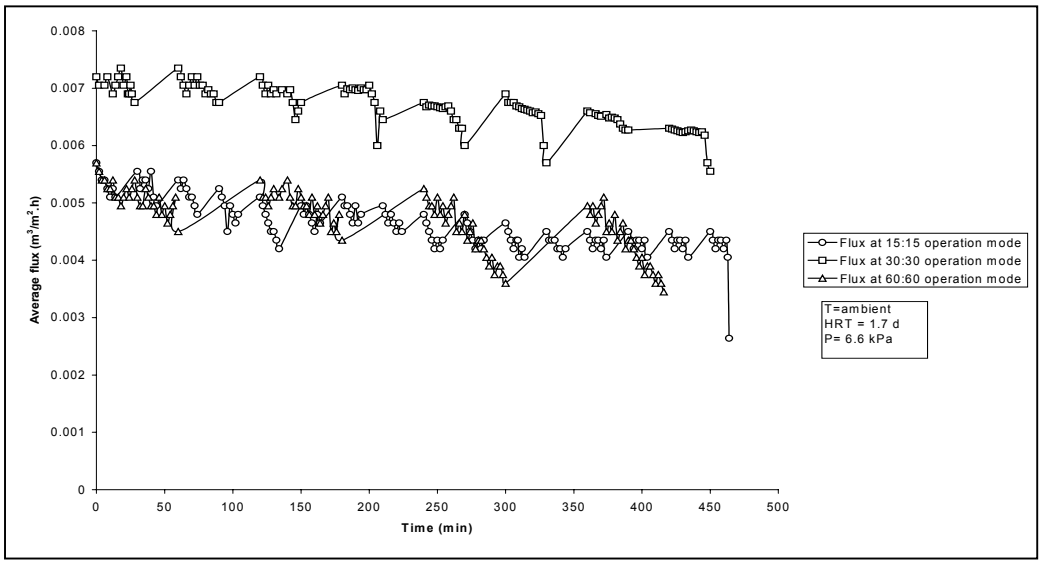

Figure 2: Flux value at different operation mode

The concentrations of the heavy metals are analyzed by using Atomic Absorption Spectrophotometer (AAS). As can be seen from Figure 3, the removal percentage of Pb gives the highest value of removal percentage at any mode of operation followed by Cd, Zn and finally Cu. However, the removal percentage of the Cd is the highest at mode operation of 30 minutes which has a value of 97%. The similar pattern is also being observed for Zn removal that has percentage of 83%. Again it shows that at 30 minutes mode of operation, it will give the highest values compared to other mode of operation whilst for organic matter removal which can be represent as COD concentration gives almost the similar removal percentage which is around 96% at any mode of operation. Other researchers found that high removal of organic matter in bioreactor which is more than 90% [8], [9] and also high removal of heavy metal (such as Pb, Cu, Cr) were also reported which is between 70-90% [3] can be obtained.

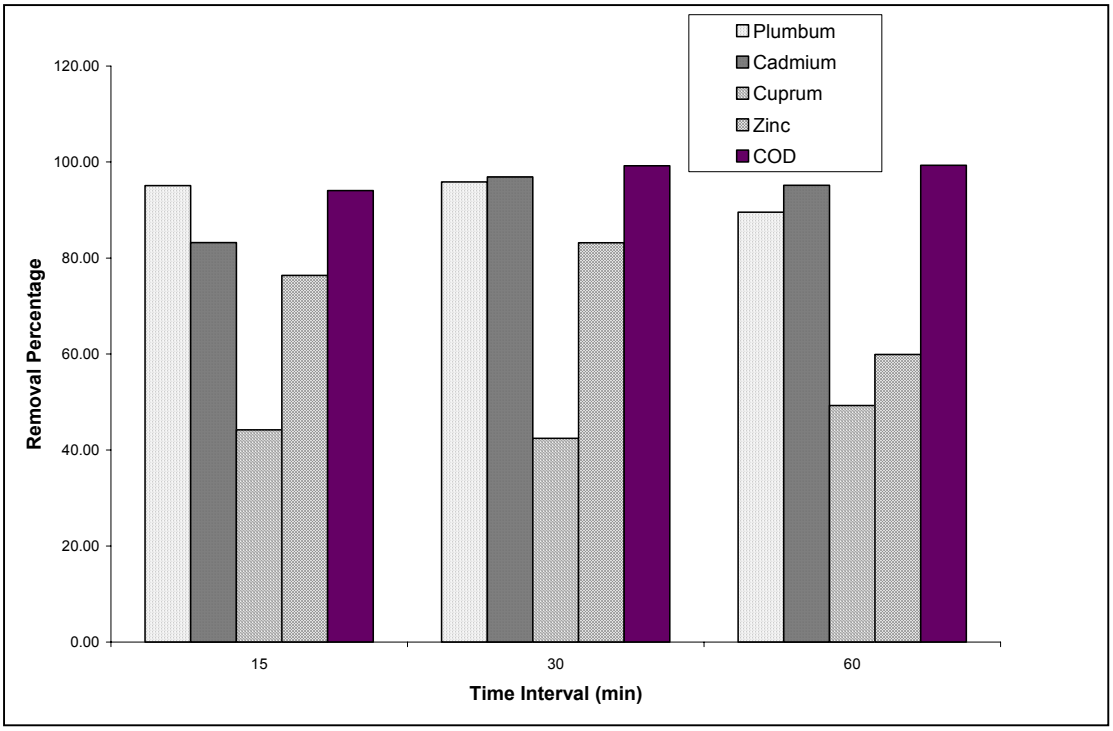

Figure 3: Removal percentage of heavy metal and COD at different mode of operation

4.0 Conclusion

The mode operation of 30 minutes give good results of removal percentage of organic matter and heavy metals compared to other mode of operations. Besides, the permeate or flux rate values obtained from the experiment is also the highest. However further studies are needed to investigate on the optimum condition of the MBR to be operated i.e. membrane pressure, operation mode and air sparging instead of reusing the permeate. This experiment found that the organic matter removal was up to 98%. The average heavy metals removal was 94%, 92%, 42% and 75 % for Pb, Cd, Cu and Zn respectively..

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