Advanced Treatment of Landfill Leachate Effluent Using Membrane Filtration

Hamidi Abdul Aziz1,*, Chae Tyng Feng1, Mohammed J. K. Bashir2

1School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, 14300, Nibong Tebal, Penang, Malaysia,
2Department of Environmental Engineering, Faculty of Engineering and Green Technology, Universiti Tunku Abdul Rahman, 31900, Kampar, Perak, Malaysia Phone, modbashir@gmail.com
*Corresponding Author: cehamidi@eng.usm.my

Received 14 February 2013; Accepted 02 March 2013

Abstract. Treatment of water by membrane filtration process has been well established. However, its application on landfill leachate effluent treatment is quite limited. This study was undertaken to investigate suitability of this process on leachate effluent treatment generated from Pulau Burung semi aerobic sanitary landfill. Three types of membrane namely Nylon, Resin and Poly-propylene (PP) were used in this study. The pore sizes were 1 µm and 5 µm. The effects of different filtration rates on leachate treatment were studied. The parameters studied were COD, colour, suspended solids (SS) and turbidity. A set of batch studies were carried out in order to evaluate the effectiveness of the membrane filtration process in leachate effluent treatment. The results indicated that Poly-propylene membrane with pore size 1 µm had the best performance in reducing all the parameters whereas the Resin membrane gave the poorest results. It can be deduced that the filtration rate of 10 mL/min exhibited the highest removal efficiency. Poly-propylene membrane with pore size 1 µm and at filtration rate of 10 mL/min was found to be the most effective membrane to remove COD, colour, SS and turbidity.

Key words: Membrane filtration, landfill leachate, advanced treatment, Poly-propylene membrane.

1. INTRODUCTION

Landfilling has remains as the most common method for the disposal of municipal solid wastes generated by different communities in Malaysia. One of the typical problems that associate with the landfilling method is generation of the leachate. Al-Hamadani et al. (2004) reported that landfill leachate is a heavily contaminated and a likely hazardous liquid that is produced as a result of water infiltration through solid wastes generated industrially and domestically. Leachate can migrate away from landfill; it may cause serious pollution to the groundwater aquifer as well as adjacent surface water. Consequently, one of the major issues to deal with is the collection, storage and suitable treatment of highly contaminated leachate (Baig et al., 1999). The impact of landfills is also long term. This is due to the fact that landfills will continue to produce leachate and release biogas for a long period after closure (Bashir et al., 2012). Therefore, biological treatment and physicochemical treatment techniques such as activated sludge treatment, rotary disc, sedimentation with coagulation, activated carbon adsorption, membrane processes have been widely used in leachate treatment. These methods can contribute to the removal of chemical oxygen demand (COD), biological oxygen demand (BOD2), metals, suspended solids, colour, and ammonia (Agamuthu, 2001).

Membrane technologies other than simple osmosis like electrodialysis and ultrafiltration are not common in leachate treatment due to the fact that most membrane technologies will suffer from problems that associated with blockage of the membranes. This is because the membrane surface and inside the membrane process are deposited by inorganic, organic and microbiological substances (Wiszniocki et al., 2005). Membrane processes deal in separating two solutions with different concentrations by a semi permeable membrane. In this process, pressure is added to the more concentrated solution, forcing the water to flow from the higher concentration to the lower concentration. Microfiltration (MF) and ultrafiltration (UF), operated singly or in combination with reverse osmosis (RO) and nanofiltration (NF) are membrane processes applied in landfill treatment (Bodzek, 1999; Trebouet et al., 2001). Robinson (2005) reported that in the late 1980s, UF and RO systems were used to clean leachate by separating and concentrating the solids. Due to the high ability of modern high-rejection osmosis membranes to retain both organic and inorganic contaminates, an efficiency level of 98–99% can be achieved (Peters, 1998). The results of tests carried out with membranes in a previous research project suggested that membrane filtration could be effective for solid or liquid separation. One of the major disadvantages of these membrane processes is fouling or biofouling of the membrane, induced by deposits of inorganic,
organic and microbiological substances on both the membrane surface and inside the membrane pores. Successful application of membrane technology for the treatment of the landfill leachate requires an efficient control of membrane fouling (Trebovet et al., 2001 and Bodzek, 1999). The removal of potential foulants including dissolved organic and inorganic substances, colloidal and suspended particles can be achieved by pH adjustment, pre-filtration and coagulation.

This study was carried out to study the effect of filtration rate, filter pore size and different membrane type in removing suspended solids, colour, turbidity and COD from pre-treated landfill leachate. Also, to investigate the efficiency of the different membrane, i.e. Nylon, Resin and Poly-propylene (PP) with pore size 1 µm and 5µm. Its focused on Pulau Burung Sanitary Landfill is a semi-aerobic landfill which is situated within Byram Forest Reserve in Penang, Malaysia.

2. MATERIALS AND METHODS

2.1. Sampling and Characterization

Effluent leachate samples were collected from final sedimentation tank of the Pulau Burung landfill (PBL) leachate treatment plant before it is discharged to the drain. Figure 1 shows the schematic diagram of the treatment procedures in PBL treatment plant.

![Schematic Diagram](image)

Fig. 1: The schematic diagram of the treatment procedures in PBL treatment plant

The samples were transported to the laboratory and stored in a refrigerator at 4°C to minimize biological and chemical reactions according to the Standard Method of Water and Wastewater (APHA, 2005). The samples were analyzed for COD, colour, suspended solids (SS) and turbidity to determine its initial values. COD was measured based on the closed reflux, colorimetric method by DR/2010 spectrophotometer. SS determination was conducted using the Photometric Method by DR/2010 spectrophotometer. SS was measured at 810 nm wavelength (program number 630). The unit of suspended solids is in mg/L and the range is from 0 to 750 mg/L. Turbidity was determined by Attenuate Radiation Method (direct reading), by DR/2010 spectrophotometer. Turbidity was determined at 860 nm wavelength (program number 750). The unit for turbidity is FAU (Formazin Attenuation Unit) and the range is from 0 to 4400 FAU. Colour was measured by APHA Platinum-Cobalt (PtCo) standard method, by DR/2010 spectrophotometer. Colour was measured at 455nm wavelength (program number 120) and the range is from 0 to 500PtCo. Before each determination, samples were filtered with filter paper with pore size 0.45µm and the distilled water was used as blank. The characteristics of the samples are demonstrated in Table 1.
2.2. Experimental Procedure

Firstly, a tank size 350 mm × 550 mm × 400 mm was chosen as the membrane reactor. Since gravity flow was used in this system, the bottom of the tank was drilled and the hole was connected with a pipe. In order to increase the pressure head of the leachate effluent, the reactor was placed on the table. The pipe was connected with a valve which is used to control the filtration rate of the leachate effluent. The flow system was then connected as shown in Figure 2.

![Diagram of experimental set up of the reactor](image)

The effect of filtration rate from (10 to 50 ml/min) in removing suspended solids, colour, turbidity and COD were studied. Poly-propylene membrane with pore size 5 µm was used in this study. Furthermore, a series of experiment carried out to study the efficiency of different types of membrane filters (Nylon, Resin and Poly-propylene (PP) with pore size 1 µm and 5µm). Besides that, the effect of pore size of membrane also studied by comparing the results obtained by PP (1 µm) and PP (5µm) membrane. Each filtration was continuously run for 4 days in a week. Daily changes of each parameter were determined. At the end of each week, the removal percentage of each parameter was determined for each of flow rate and each type of membrane filter using standard methods (APHA, 2005).

Table 1: Characteristics of pre-treated leachate at PBL

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>630</td>
<td>220</td>
<td>425</td>
</tr>
<tr>
<td>Colour</td>
<td>Pt Co</td>
<td>128</td>
<td>96</td>
<td>106</td>
</tr>
<tr>
<td>SS</td>
<td>mg/L</td>
<td>63</td>
<td>21</td>
<td>40</td>
</tr>
<tr>
<td>Turbidity</td>
<td>FAU</td>
<td>106</td>
<td>34</td>
<td>67</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

3.1. The effect of filtration rate on the removal efficiency

**Colour Removal:** Lower filtration rate exhibited better removal of colour as demonstrated in Fig.3. This is may be due to the higher retention time. Colour removal efficiency at all filtration rates were fairly low and in the range between 4 to 18%. This is may be due to the suspended solids and turbidity removal in this study was not very good, therefore, the overall results for colour removal was also very low (< 20%). The presence of ion metallic or organic dissolved matters like humic substance (Zouboulis et al., 2004) in leachate effluent which can pass through the membrane filter.

**COD removal:** Fig. 3 shows the effected of filtration rate on COD removal, COD removal efficiency increased when the filtration rate was decreased. The COD removal efficiencies were 38.6
%, 34.8% and 22.2% obtained at filtration rates of 10, 20 and 30 ml/min, respectively. According to Vogel et al. (2000), it is difficult to achieve lower COD value in leachate effluent. It may be caused by higher ammonia level in leachate as ammonia is a difficult inorganic matter to oxidize or reduce. Vogel et al. (2000) also pointed out that one third ($\frac{1}{3}$) of the COD in leachate is influenced by the inorganic matters such as Fe (II), manganese (II), sulphide, ammonia and chloride. Therefore, the achievement was very low for this case in simple membrane filtration process.

**SS Removal:** The SS removal at filtration rate of 50 mL/min was very low (about 54%) compared to the others. At filtration rate of 40 mL/min, removal fluctuates from first day to third day of experiment. At filtration rates of 30 and 40 mL/min, the removal were almost same at the end of the experiment. Good removal of SS was observed at filtration rate of 10 and 20 mL/min, with 78% and 71% reduction, respectively. It can be concluded that low filtration rate can give good results in removing the SS due to higher retention time. The overall removal of SS achieved by membrane filter, Poly-propylene (5 µm) was below 80%. This may be caused by the dissolved matter and colloidal materials which is available in the leachate. These type of materials can pass through the micro-membrane and normally it is called permeate (Ziyang and Youcai, 2007). Graph of particle size distribution on the filtrates sample at filtration rate of 10 mL/min (Fig. 4), indicated that about 28% of the particulate in leachate are less than 5µm. This means that at least 28% of the particulate can pass through the micro-membrane and remained in the samples.

**Turbidity Removal:** Fig. 3 shows turbidity removal efficiency at different filtration rates. The results were similar as the case of SS removal. As seen from Fig. 3, the turbidity removal efficiency at all filtration rates were low and in the range of 45 to 77%. This is due to the SS in leachate can contribute greatly to the turbidity (Ziyang and Youcai, 2007).

---

**Fig. 3:** The effect of different filtration rates on A) colour, B) COD, C) SS, and D) Turbidity, removal efficiency
3.2 Effect of different membrane type on the removal efficiency

The effect of different types of membranes, i.e. Nylon, Resin and Poly-propylene (PP) on the removal of colour, COD, SS and turbidity were carried out by using constant filtration rate of 10 mL/min. The effect of pore size of membrane was also studied by using PP (1 µm) and PP (5 µm).

**Colour Removal:** Nylon membrane exhibited the highest colour removal as illustrated in Fig.5, which ranging from 18-24%. Besides that, there was no significant different on the removal of colour by PP (1 µm) and PP (5 µm) membranes. The removals obtained by both were in the range of 10 to 20%. The colour removal by Resin membrane was fairly low, which was less than 12%. However, all the membranes did not give very good results (< 24%). As previously stated, this may be due to the presence of ion metallic or organic dissolved matters like humic substance (Zouboulis et al., 2004) in leachate effluent which can pass through the micro-membrane and remained in the leachate (Ziyang and Youcai, 2007). Thus, poor result for colour removal was obtained in this study.

**COD Removal:** Fig. 5 (B) shows that the COD removal by PP (1 µm) and PP (5 µm) membrane were greater than 35%, which was 41.7% and 38.6%, respectively. There was no significant dropped on the removal for these two membrane. However, for Nylon membrane with pore size 5 µm, the percentage of COD removal dropped to 21.0%. The removal for Resin membrane with pore size 5 µm was less than 13%. Besides that, it can be deduced from Figure 4 that smaller pore size exhibited higher removal of COD. The range of percentage of COD removal by 1 µm membrane was 28 to 42% as compared with 18 to 38% at 5 µm.

**SS Removal:** Fig. 5 (C) shows SS removal efficiency by using different types of membrane filters at constant filtration rate (10 mL/min). Percentage of SS removal using the Resin membrane was very low with only 51% reduction. In addition, it can be deduced from Figure 4 that there was no significant different on the removal of SS by Nylon, PP (1 µm) and PP (5 µm) membranes. The removals for these membranes were in the range of 74 to 84% of SS removal. PP (1 µm) has the best performance in removing SS from the leachate effluent. This is because it has the smallest pore size compared with the others.

**Turbidity Removal:** Fig. 5 (D) shows turbidity removal efficiency by using different types of membrane filters at constant filtration rate, 10 mL/min. There was no significant different on the removal of turbidity by PP (1 µm), PP (5 µm) and Nylon membranes. The removals for these membranes were in the range of 54 to 86%. However, the range of turbidity removal was between 10 to 53% for Resin membrane. Most of the results had almost similar trend with the SS removal. As can be seen from Fig. 5, all the lines have almost similar trends with the SS removal. This is due to the suspended solids can contribute to the turbidity of the leachate (Ziyang and Youcai, 2007). Therefore, once the SS were removed, the turbidity of the leachate also decreased.
4. CONCLUSION

From the previous results, the best performance of COD, colour, suspended solids and turbidity removal efficiency achieved at filtration rate of 10 ml/min were 38.6%, 18.0%, 78.3% and 76.7% respectively, whereas 50 mL/min gave the poorest results for all parameters removal except for colour. Removal efficiency of COD, colour, suspended solids, and turbidity removal was increased by using low filtration rate. Poly-propylene (PP) was the most efficient on parameters removal as compared with the others. However, PP (1 µm) performance was better than PP (5 µm), the result shows 41.7% removal of COD, 84.4% removals of SS and 86.2% removal of turbidity. Nylon membrane (5 µm) was most efficient on colour removal as compared to the others (22.6% of colour removal). Removal of colour was not really efficient with membrane filtration method. Thus, other treatment method such as coagulation and flocculation method may be studied further. Ferric chloride can also be used to remove colour.

REFERENCES

Dr. Aziz is a Professor in environmental engineering at the School of Civil Engineering, Universiti Sains Malaysia. Dr. Aziz received his Ph.D in civil engineering (environmental engineering) from University of Strathclyde, Scotland in 1992. He has published over 200 refereed articles in professional journals/proceedings and currently sits as the Editorial Board Member for 8 International journals. Dr Aziz's research has focused on alleviating problems associated with water pollution issues from industrial wastewater discharge and solid waste management via landfilling, especially on leachate pollution. He also interests in biodegradation and bioremediation of oil spills.

Mr. Chae Tyng Feng received his B.Sc. degree in Civil Engineering from School of Civil Engineering, Universiti Sains Malaysia (USM), Malaysia.

Dr. Mohammed J.K. Bashir is an Assistant Professor in environmental engineering at the faculty of engineering and green technology, Universiti Tunku Abdul Rahman (UTAR), Malaysia. Dr. Bashir received his B.Sc. degree in Civil Engineering from Islamic University of Gaza, Palestine. He received M.Sc and Ph.D in Environ. Eng. from School of Civil Engineering, Universiti Sains Malaysia. He received several award and has published many refereed articles in professional journals/proceedings. Dr. Bashir's research has focused on wastewater treatment, solid and hazardous waste management, environmental sustainability.