Initial Characterization of Semi-aerobic Landfill Leachate Based On Its Biodegradation

Ng Kar Kin, Hamidi Abdul Aziz*, Amin Mojiri

School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, MALAYSIA

*Corresponding Author: Email: cehamidi@usm.my

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Abstract. The characterization of landfill leachate has been well established. However, its biodegradation properties have not been well reported. Therefore, this research was undertaken to investigate the biodegradability of semi-aerobic sanitary landfill and the ratio of the biological oxygen demand (BOD) to chemical oxygen demand (COD) BOD/COD, COD fraction on leachate from Pulau Burung landfill Site (PBLs). These parameters are important as they may provide appropriate and suitable treatment for this kind of leachate. In this research, leachate from two different ponds were studied i.e., the raw leachate from leachate collection pond and the leachate effluents of the treatment plant. Five different measurement points were tested for each pond to understand the characterization for leachate. The soluble and particulate organic compound was separated by filtration using a 0.45μm pore size membrane filter. The results indicated that leachate in PBLs has low BOD/COD ratio. The total COD (TCOD) ranged from 2040mg/L to 3160mg/L. The Biodegradable COD (BCOD), unbiodegradable COD (UBOD), soluble biodegradable (RBCOD), particulate biodegradable (SBCOD), particulate inert (UPCOD), and soluble inert (USCOD) ranged from 53%-67%, 33%-47%, 38%-46%, 9%-25%, 12%-26%, and 18%-25%. This indicates, the leachate in Pulau Burung Landfill Site have different of COD fraction behavior compare with domestic wastewater. In which, leachate have low SBCOD, but relatively high in others COD fraction compare with domestic wastewater.

Keywords: Leachate, semi-aerobic, biodegradation, BOD, COD fraction.

1. INTRODUCTION

At present, biological processes (both aerobic and anaerobic) constitute of the solid wastewater treatment. Highly concentrated leachates with a complex molecular composition are released at most of municipal waste landfills (Franke et al., 2007). These leachates often comprise highly polluted wastewaters that contain abundant biodegradable or refractory organic matter, including humic-type constituents (Nanny et al., 2002).

Therefore, to provide a general basis for design and operation of leachate treatment plant, it is necessary to provide a rational description of related processes in terms of microbial kinetics, emphasizing the required wastewater characterization for the assessment of biological treatability. Although this rational approach is now adopted from domestic wastewater treatment plants, it is still largely overlooked in the treatment of leachate. Besides, the high variability of leachate composition and, the different biodegradability characteristics of the effluents of each industrial category make characterization essential for an appropriate design of a treatment plant (Del Pozo et al., 2003). Due to reliability, simplicity and high cost-effectiveness, biological process is commonly used for the removal of the bulk of leachate containing high concentrations of BOD (Renou et al., 2007). It has proven the ability in large scale effluents and high BOD remove in municipal waste water. Besides that, biological process also can as part of the physic-chemical treatment processes. However, its application on semi-aerobic leachate is not as the leachate has been stabilized. Knowledge of its biodegradability is important to further understand the suitable leachate treatment process for this kind of leachate.

This research will concentrate on the biodegradable behaviors of leachate in term of TCOD, BCOD, UBOD, RBCOD, SBCOD, USCOD, and UPCOD. By studying the biodegradable of leachate, more suitable treatment process may introduce in the future.

2. MATERIALS AND METHODS

Samples were taking from 2 different ponds from 25th November 2008 to 17th February 2009. They are raw
leachate collection pond (pond 1) and leachate effluent was taken before it is discharged to the nearest drain. 5 difference measurement points will be tested for each pond. The collected leachate was brought back to the Environmental Engineering Laboratory. The transportation to the laboratory took about 25 minutes. Leachate was stored in a cold room in the laboratory at 4°C to minimize biological and chemical reactions according to the Standard Method of Water and Wastewater (APHA, 1992).

The BOD curve was determined by continuously BOD tests using dilutions method. The BOD test was measure everyday continuously until a constant BOD value shows. After that, the BOD value again time was plotting to obtain the BOD curve. In this study 2 different dilutions were using which are 1 to 200 and 1 to 1000.

The $k_{\text{BOD}}$ value was obtain from the BOD curve. In this study, day 5 BOD and ultimate BOD was use in determine $k_{\text{BOD}}$. The equation used to determine $k_{\text{BOD}}$ (1) is shows as below:

$$BOD_s = BOD_{s0} \times (1 - e^{-k_{\text{BOD}} \times t})$$  (1)

After that, total COD and BODs was measured by raw influent leachate. Besides that, both influent and effluent sample was filtrated by using 0.45μm membrane filter paper and the COD was measured.

The calculations of COD fractions are using from Roeleveld and Van Loosdrecht 2002. The formulas use to calculate ultimate BOD (2), USCOD (3), RBCOD (4), SBCOD (5), and UPCOD (6) as below:

$$C_{s0}$$

$$BOD_s = 1.18$$  (2)

$$COD_{\text{eff, sol}} = S_f$$  (3)

$$COD_{\text{inf, sol}} = S_s + S_f$$  (4)

$$X_s = C_s - S_s$$  (5)

$$X_f = C_f - S_f - X_s - S_s$$  (6)

3. RESULTS AND DISCUSSIONS

Table 1 shows the characteristics of leachate effluent samples that were collected from Pulau Burung Landfill Site from 25th November 2008 to 17th February 2009 while Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$C_T$ mg/L</th>
<th>$\text{COD}_{\text{inf, sol}}$ mg/L</th>
<th>$\text{COD}_{\text{sol}}$ mg/L</th>
<th>$\text{BOD}_5$ mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td>2704</td>
<td>1705</td>
<td>674</td>
<td>212</td>
</tr>
<tr>
<td>Set 2</td>
<td>2688</td>
<td>1739</td>
<td>575</td>
<td>175</td>
</tr>
<tr>
<td>Set 3</td>
<td>2855</td>
<td>1843</td>
<td>520</td>
<td>224</td>
</tr>
<tr>
<td>Set 4</td>
<td>2787</td>
<td>1730</td>
<td>558</td>
<td>230</td>
</tr>
</tbody>
</table>

Below are 2 BOD curve plot by using 2 different dilutions:

Fig. 1: BOD Curve for 1:200 Dilutions

Fig. 2: BOD Curve for 1:1000 Dilutions

2 different dilution ratios were used to produce BOD curve. Figure 1 shows a dilution of 1:200. From the graph, it shows that oxygen consumption is slow from day 1 to day 5 with 46mg/L/day. However, the oxygen consumption rate increases dramatically after day 5 with 426mg/L/day. After day 8, all the samples show insufficient of oxygen for further consumption. Therefore, the dilution ratio is inappropriate because further biodegradation activities may occur if oxygen present.

In the Figure 2, dilutions of 1:1000 have been used. From the graph 2, the initial oxygen consumption rate was slow (day 1 to day 4) with 128mg/L/day. However, oxygen consumption increases dramatically from day 4 to 5 as figure 1 with 4850mg/L/day and trend to constant after day 5. However, some samples showing insufficient of oxygen for further consumption during experiment. Therefore, dilution of 1:1000 is the minimum dilution ratio has to be use. Both the BOD curve due to leachate possesses the similar shape of BOD curve due to other wastewater such as domestic wastewater but leachate has slow initial biodegradation process. Then, the process increase rapidly until an ultimate state and the curve remain constant. For domestic wastewater, biodegradation process increase rapidly after one to three hour due to RBCOD but leachate need about 4 to 5 days.

A reliable BOD curve is important in determining the COD fraction. However, observation shows that ultimate BOD value (Figure 2) 7100 mg/L is larger than maximum total COD (3147mg/L) in which total COD should be smaller than the ultimate BOD.

By comparing the physical shape behavior of BOD curve to a similar case, we are able to predict the ultimate BOD of leachate which is based on the nature behavior of the BOD curve’s shape. This method is
adequate because biodegradation of leachate in PBSL behave like other wastewater and similar to previous study by other researchers. It also does not require further modeling and large set of data.

By comparing the oxygen uptake rate produced by Figure 3 (Ince et al., 2007) with BOD curve are similar in:
(a) Low oxygen uptake rate at the initial and end of the test.
(b) Oxygen uptake rate increases rapidly in a certain time interval.
(c) Shapes of the graphs are same as the natural behavior of BOD curve.

Therefore, we are able to predict the further biodegradation by extending the BOD curve by compare with the existing BOD curve.

By projecting the Figure 1 with reference Figure 3 we get.

4.3 BOD₂/COD

In general, BOD₂/COD ratio represents the proportion of biodegradable organics in leachate. Landfill leachate from a young landfill usually had a higher BOD₂/COD ratio and a leachate from an older or stable one had a lower BOD₂/COD ratio. Also the characteristics of leachate change over time as the landfill ages, therefore the system should also be flexible in adapting itself to changing BOD₂/COD ratios in leachate over time (Ince et al., 2007). Therefore, from previous study the expected BOD₂/COD ratio for PBLS should has high BOD₂/COD ratio due to the young age of landfill leachate. But the BOD₂/COD ratio range from 0.07 to 0.12, this shows that leachate in PBLS has relatively low biodegradability compare to 0.4–0.5 BOD₂/COD which is easily biodegradable (Ince et al., 2007). Therefore, the Biodegradability of PBSL is low.

The low BOD₂/COD is because PBSL is a semi-aerobic landfill site. Compared with an anaerobic landfill treatment, the concentrations of BOD and COD in leachate were slightly lower in the semi-aerobic landfill (Huang et al., 2008). Therefore, leachate in PBCL has low BOD₂/COD ratio as well as low biodegradability.

Table 2: COD Fraction from Pulau Burung Landfill Site
(all units in %)

<table>
<thead>
<tr>
<th>S₁</th>
<th>S₂</th>
<th>X₁</th>
<th>X₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>set 1</td>
<td>25</td>
<td>38</td>
<td>25</td>
</tr>
<tr>
<td>set 2</td>
<td>21</td>
<td>43</td>
<td>9</td>
</tr>
<tr>
<td>set 3</td>
<td>18</td>
<td>46</td>
<td>17</td>
</tr>
<tr>
<td>set 4</td>
<td>20</td>
<td>42</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 3: Comparison of COD Fraction with Other Wastewater

<table>
<thead>
<tr>
<th>Wastewater</th>
<th>S₁ %</th>
<th>X₁ %</th>
<th>X₂ %</th>
<th>S₂ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>9</td>
<td>77</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Leachate</td>
<td>42</td>
<td>19</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>Slaughterhouse</td>
<td>61</td>
<td>33</td>
<td>6</td>
<td>(X₁+S₂)</td>
</tr>
</tbody>
</table>

From table 3 both domestic and industry wastewater have similar COD fraction behavior which have high COD in certain type of COD fraction. However, leachate has a more even distribution of COD fraction compare to the other 2 types of wastewaters. From table 3, domestic and industry wastewater are mainly consists of certain type of waste. For domestic wastewater, it usually consists of wastewater from residential whereas landfill contains solid waste which is highly variable and heterogeneous. Besides that, it has undergone a complex semi-aerobic process in a high pressure condition. Leachate composition and characteristics strictly depend upon various factors such as waste type, climate, organic matter content, landfill hydrogeological structure, and operational conditions (Bilgili et al., 2008). This shows that leachate cannot classify into any specific group of wastewater.

The TCOD ranges from 2040mg/L to 3160mg/L. This shows that the PBSL leachate have a relatively low in COD compare with other landfill leachate such as 13800mg/L in Canada, China Hong Kong 50000mg/L, South Korea 24400mg/L. (Renou et al., 2007)
BCOD consists of RBCOD and SBCOD. From the data, the BCOD are in the range of 53% to 67%. However, even though the BCOD are more than 50% of COD fraction, but we still cannot classify leachate as a strong biodegradable wastewater. It is because leachate has a low $\text{BOD}_5/\text{COD}$ ratio (0.07 to 0.12). Besides that, most of the biodegradation processes increase rapidly after 5 to 6 day of biodegradation. Thus, the slow initial biodegradation process and low $\text{BOD}_5/\text{COD}$ cause leachate unfavorable for biological treatment process.

The UCOD consists of USCOD and UPCOD which are unbiodegradable. From this study, UCOD has relatively smaller portion then BCOD which ranges from 33% to 47% compare to BCOD. However, the UCOD has relatively higher COD fraction than domestic wastewater which result in low biodegradable. It is interesting to find that the UCOD are less than BCOD and not agree with previous research. This is because research results have shown that semi-aerobic landfill can not only accelerate the landfill stabilization process and reduce organic substance concentration in leachate and the production of methane in semi-aerobic landfill, but also reduce ammonia concentration in leachate (Huang et al., 2008).

The RBCOD are one of the COD fractions which can be biodegradable. From this research we found that it is the biggest COD fraction in leachate, which contain 38% to 46%. In domestic wastewater, the RBCOD contribute the initial biodegradation process (1 to 3 hours). RBCOD also has the fastest degradation rate compare to other COD fraction due to the smaller size. However, it is found that, the leachate in PBSL has high RBCOD but slow in initial biodegradation rate. Future research requires the identification of the cause of high RBCOD but low initial biodegradation. The high RBCOD also cause by the young age of leachate. Therefore, landfill leachates age will give various RBCOD. Future research requires a better understanding of the relationship between biodegradable of leachate, COD fraction and age of landfill. RBCOD concentration is important because this fraction is conceived as the rate limiting substrate component for heterotrophic growth (Orhon et al., 1996). Leachate has high RBCOD shows that no rate limiting substrate component for heterotrophic growth occurs.

SBCOD ranges from 9% to 25% and UPCOD consists of 12% to 26% in COD fraction. It shows that, leachate has higher particulate compare to domestic and slaughterhouse wastewater. From the BOD curve, it shows that the biodegradation will be continuous for few days. The long period of biodegradation is due to the large size of SBCOD. Therefore, leachate has slow initial biodegradation process due to the behavior of RBCOD and large particulate of SBCOD which result a long biodegradation process (4 to 5 days-from high until no degradation).

From the result, the USCOD consists of 18% to 25% or 520.4mg/L to 674.20mg/L which contribute to the unbiodegradable portion. USCOD in leachate are higher compare with domestic wastewater. It shows that, leachate have lower biodegradability compare to domestic wastewater. The total COD of soluble COD is 62% to 65% shows that soluble COD are dominating in leachate. This shows the same result as Ziyang and Youcai (2007) where dissolved matters are predominant in fresh leachate.

Filter with pore sizes of 450μm help to identify the size of particles that can be removed by means of chemical settling (Dogruel et al., 2006). Therefore, RBCOD is relatively small particulate size compare with other COD fractions. USCOD and RBCOD are too small (<0.45μm) which make it not suitable for physical and chemical settling treatment process. Besides, the unbiodegradable behavior make USCOD cannot be removed by biological process.

Therefore, for soluble COD fraction ultrafiltration becomes a solution. It contributes to a very compact system working with a high biomass concentration and achieving a low sludge production with an excellent effluent quality. Membrane bioreactors have been widely applied at full scale on industrial wastewater treatment and some plants have been adapted to leachate treatment (Renou et al., 2007).

Both SBCOD and UPCOD have larger particulate which is greater than 45μm and for particulate COD (UPCOD and SBCOD) are ranges from 33% to 47%. Therefore, with huge amount of particulate COD fraction, physical and chemical settling treatment process is a suitable option (Dogruel et al., 2006). However, the particulate size distribution is important to determine the treatability of leachate by physical and chemical settling. By understanding the particulate size distribution of leachate, we can easily find out the reagent or biological treatment process which is suitable while future research will require a better understanding of size distribution of leachate.

4. CONCLUSION

It could be conclude that, leachate has the same biodegradation behaviour as the others types of wastewater such as domestic wastewater. However, leachate has low biodegradation due to the slow biodegradation of BCOD and relatively large UCOD compare with domestic wastewater. Leachate also has low $\text{BOD}_5/\text{COD}$ which is in the range of 0.07 to 0.12. The COD fractions are TCOD ranges from 2040mg/L.
to 3160mg/L. Compare with domestic wastewater COD fraction:
(a) High BCOD 53% to 67%; (b) High UCOD 33% to 47%; (c) High RBCOD 38% to 46%; (d) Low SBCOD 9% to 25%; (e) High UPCOD 12% to 26%; (f) High USCOD 18% to 25%.
In which, shows that leachate has a more even distribution of COD fraction compare with domestic wastewater.

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Ng Kar Kin is a student at School of Civil engineering, Engineering Campus, Universiti Sains Malaysia (USM).

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.

Amin Mojiri is a PhD candidate in environmental engineering, School of Civil Engineering, Universiti Sains Malaysia (USM), Pulau Pinang. He is fellowship holder and research assistant at the School of Civil Engineering (USM). He is a member of Young Researchers Club, Islamic Azad University, Iran. He is editor and reviewer of some international journals. His area of specialization is waste management, waste recycling, wastewater treatment, wastewater recycling, and soil pollutions.