Treatment of Landfill Leachate: COD, BOD and TSS Removal in Padang Siding Perlis Using Bio-Electrochemical Process

Issa Alabiad[1], Umi Fazara Md Ali[1], IrnisAzura Zakarya[1], Tijjani Adam[2]
[1]*School of Environmental Engineering, Universiti Malaysia Perlis, Kompleks Pusat Pengajian Jejawi 3, 02600 Arau, Perlis, Malaysia,*
[2]*Faculty of Engineering Technology, Universiti Malaysia Perlis, Aras 1, Blok S2, KampusUniCITIAlam, Sungai Chuchuh, 02100 Padang Besar, Perlis, Malaysia,*

Abstract
Landfill leachate is generally known as high-strength wastewater that is highly difficult to handle and contains extracted dissolved matter and suspended matter. This study presents the removal of the leachate components such as chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solid. Microbial fuel cells (MFCs) were designed to treat landfill leachate; three anodes were tested in the MFC reactor: black carbon, activated carbon, and zinc electrodes. Movements in the MFC reactor during treatment were a key factor for testing. Thus, the system was operated in different modes: static and dynamic. Both modes showed a difference in the ammonia level of the three anodes used. This study compared the static and dynamic modes of the MFC in removing ammonia. The continuous reactor movement could increase the rate of ammonia component removal. The reactor also provided a viable condition for maximum removal. The reactor movement caused the sludge to disintegrate and enabled the ammonia to separate easily from the parent leachate. This paper presents the results of leachate treatment analysis from the solid waste landfill located in Padang Siding Landfill, Perlis. Ammonia removal was enhanced using different types of electrodes. In both modes, activated carbon provided better performance than black carbon and zinc. The percentages of leachate components removal for activated carbon zinc and black carbon with dynamic mode was generally higher over static mode. The final values of the ammonia, COD, BOD and TSS, were 13 mg/l (97.66% removal), 125 mg/l (96.45% removal), 249mg/l (77.98 % removal) and 106mg/l (42.20% removal) respectively.

Keywords: *Leachate BOD, COD, TSS, Bio-electrochemical*

Introduction

Leachate is a major issue that threatens environmental quality in Malaysia. Leachate resulted from the escalation of solid waste, which comprises unwanted matter produced by human activities (Adhikari et al., 2014; Araceli et al., 2014; Aziz et al., 2011; Aziz et al., 2013). In Malaysia, the increase in urban population reflects the escalation of solid waste generation. Given its stable political conditions, Malaysia is one of the most economically successful developing countries in the world, hence the production of various products including food, automotive, crops, light and heavy industries are booming and expanding annually (Solid Waste Management and Public Management Cleansing Corporation, 2011; Zhou et al., 2010; Sani et al., 2014). These rapid economic transitions and increasing of urban population incur the escalation of solid waste generation. The urban population Malaysia has increased by over 50% over the last few decades (Tarmiji et al., 2011), and this increment has caused serious concerns regarding solid waste production (Composition Solid Waste Management and Public Management Cleansing Corporation, 2011; Zhou et al., 2010; Sani et al., 2014). By 2020, the number of city in peninsular Malaysia had increased by 400% as compared to the number of city in 1957 (Adhikari et al., 2014).
Therefore, the productions of waste are accelerating and normally the waste will end up in a landfill. As a result, the Malaysian government has imposed several rules, regulations and policies to underpin the management of waste in the country.Urbanization and industrialization in Malaysia have changed the characteristics of solid waste. Thus, effective solid waste management practices must be updated to suit the current waste quantity (Composition Solid Waste Management and Public Management Cleansing Corporation, 2011; Zhou et al., 2010; Sani et al., 2014). Landfilling has been the primary method of waste disposal in Malaysia for many decades. The Solid Waste Management and Public Management

Cleansing Corporation is one of Malaysian policy for solid waste management that was implemented in 2011 to manage all the waste produce in the country. Although the policy is being implemented currently however we have yet to see stringent measures undertaken. Due to that, Malaysia is currently facing serious landfill problems which include lack of capacity, overflowing landfill sites, serious odour without ventilation, and lack of leachate treatment facilities. Figure 1.1 reveals the real problem in Padang Siding, Perlis Landfill area which is the overflowing of rubbish that creates serious odour problems to the surrounding. The landfill is owned by the private institution that is design to abide by the rules and regulation imposed by the Government.

According to Solid Waste Management and Public Management Cleansing Corporation (2011), the privatization of landfills will contribute to improved management strategies. For example, Alam Flora was appointed to manage Kundang Landfill at Selangor, and IdamanBersih was appointed to manage PulauBurung Landfill at Penang (Composition Solid Waste Management and Public Management Cleansing Corporation, 2011; Zhou et al., 2010; Sani et al., 2014). Several landfill facilities have been upgraded through privatization such as based on the landfill capacity, the facilities need to be upgraded to levels 3 and 4. A level 3 facility is equipped with a leachate circulation system, while a level 4 facility is equipped with leachate treatment facilities (Composition Solid Waste Management and Public Management Cleansing Corporation 2011; Zhou et al., 2010; Sani et al., 2014). However, this has not been implemented in Padang Siding, Perlis Landfill as yet.

Dealing with landfill waste is an important issue for the environmental protection policy of any developing country. Landfill leachate is a major problem for municipal solid waste (MSW) landfills because it causes significant threats to surface water and groundwater. Leachate is defined as a liquid that passes through a landfill and contains extracted dissolved matter and suspended matter. Although numerous current features have somehow improved the processing of MSW landfills, several problems still remain, such as processing of leachate. Generally, leachate is characterized by high values of chemical oxygen demand (COD), pH, ammonia nitrogen, and heavy metals. Leachate also generally possesses a strong colour and bad odour. However, the characteristics of leachate also vary with its composition, volume, and condition of biodegradable matter in the leachate.

Different sources of leachate produce leachate with different quantities and compositions. Various factors influence the production and composition of leachate. One of the major factors is the climate of the landfill (Qixing et al., 2010). For example, climates with a high amount of precipitation allow a large volume of water to enter the landfill, thus producing a high amount of leachate (Zhou et al., 2010). Therefore, proper leachate treatment and control are necessary to improve aquatic inhabitant management for human welfare.To date, there are many technologies implemented and under research to tackle the problem associated with leachate at landfill area such as physical, chemical and biological processes. Malaysia is one of the first Asian countries that realize the need for sustainable environmental development and solid waste treatment in urban areas. This country has been developing since the 1980s because of rapid urbanization and the increasing diversity of its lifestyles. Increasing waste management costs and securing final disposal landfills has become one of the most serious social issues in Malaysia. In response to this emerging issue, the Malaysian government in the 8th Malaysia Plan (2001–2005) included waste minimization, promotion of reuse, developing a recycling-oriented society, and implementation of a pilot project for recycling as its main policy goals. The 9th Malaysia Plan (2006–2010) further emphasized the continuation of reducing, reuse, recovery, and recycling of waste as well as a greater use of environmentally friendly products(Adhikari et al., 2014; Araceli et al., 2014; Aziz et al., 2011; Aziz et al., 2013). In line with the basic policy framework articulated in the above plans, the Ministry of Housing and Local Government has been conducting national programs for the promotion of recycling and public awareness regarding such activities which has become the main concern as a mountain of waste has been created in most of the region's landfill.Hence, leachate must be treated effectively. To achieve this, waste must first be characterized to determine the applicability of waste treatment (Zhou et al., 2010; Zhang et al., 2013; Tong et al., 2014; Qixing et al., 2010). Generally, no advanced treatments are available at the Padang Siding Landfill, Perlis to treat leachate.

Materials and Methods

The materials and apparatus used in this research are as follows: A glass beaker (1000 mL), three glass dishes, tweezers, a vacuum flask (1000 mL), vacuum tubing, a graduated cylinder (250 mL), a glass filter holder (funnel) with rubber adapter, a drying oven, glass desiccators, an analytical balance capable of weighing 0.01 g, raw leachate samples, and distilled water, Electrode (Zinc, activated carbon, black carbon and graphite for cathode). In order to measures outcome and performance the microbial fuel cell (MFC) at each activities instance, the instrument to measure this outcome is necessary. Two (2) pH meter is required to determine pH levels and two (2) multimeter is used to determine the voltage and current produced.The chemicals needed in the MFC experiments were listed as follows; Hydroxide (OH), Hydrogen peroxide and Sulfide.The sample in the present study was collected from the Padang Siding Landfill, Perlis site. After collecting the sample, its physical and chemical characteristics, including ammonia, BOD, COD, and TSS were determined. The sample was collected from five sampling points of the landfill site. The sample was sun-dried for laboratory tests .The sampling equipment includes a canister (2.0 L), gloves, and a sampling rod. The surface area of the leachate sampling point exceeded 200 cm2, but the depth only reached 0.5 m. The sample was taken from the leachate sampling point by using a sampling rod.The leachate sample was pre-treated before characterization because unwanted contaminants could affect the final result of the process. Pre-treatment was conducted to clean the sample of unwanted substances, such as leaves, sticks, and animal feathers, which were excluded from the sample. If the unwanted substance was included within the sample, then the determination of final result would be influenced and would contain error. The pre-treated sample, was characterized for TSS, BOD, and COD then refrigerated prior to final treatment. pH measurement, and alkalinity provides information needed to quickly measure the state of each reactor; rather, the performance of the nitrification and denitrification process in leachate, and associated with organic matter successfully from the system (López-Palau et al.,2012).The pH of the sample was characterized to understand the sample pH value. The TSS characterization involved three major steps: solid particle collection before the weighing process, solid particle collection after the weighing process, and calculation. The measurement of the total suspended particle (TSS) was conducted in order to find out how much solids is in the samples. The procedure for this test were done as follows, the filter paper was weighed paper and was transferred to in the Buchner funnel. Vacuum was turned on, the measured of the leachate was prepared and after process the solid particle appeared above the paper. Tried was then measured the measurement was done according the equation 3.1.

$$Total\ suspended Particle(g/ml) = \frac{(A-B)X1000}{Sample(ml)}$$

Where:
A = weight of filter + dried residue, g, and
B = weight of filter paper, g.
This followed by BOD CharacterizationBOD is defined as the amount of oxygen required by microorganisms to stabilize decomposable organic matter at a particular time and temperature Kolhe and Pawar (2011). BOD was a measurement of the oxygen consumed by present microorganisms to decompose landfill components. If the landfill components contain a large quantity of organic waste, then a large amount of bacteria will be required to decompose the landfill components. Furthermore, the demand for oxygen will be high and, subsequently, the dissolved oxygen levels in the leachate may begin to decline. BOD was measured daily over 30 days. The measurement of BOD was conducted, prior to the testing and the sample prepared and put the BOD test sample bottle. The testing was conducted by BOD manometer to determine the amount of the BOD presents. The measured sample was kept in dark freezer for 5 days. After sample was removed for treatment, after the treatment, the BOD is measured again.The was equally COD Characterized, this process involved the measurement of the oxygen equivalent consumed by organic matter in a sample during strong chemical oxidation. The characterization was conducted as follow. The vials for each sampling procedure were prepared, and every vial was labelled and cleaned with distilled water before use. Then every vial was filled with 3.0 mL of digestion reagent and 2.0 mL of the sample. A vial consisted of; 2.0 mL of distilled water and 3.0 mL of digestion reagent was saved as control. Lastly, the samples were refluxed for 2 h using a COD reactor at around 150 °C. The samples were tested with a Spectrophotometer HACH Model DR2000 to obtain the COD value.

An MFC has two chambers: an anode chamber for placement of the sample and a cathode chamber where most of the reactions will occur, as shown in Figure 3.9.
The MFC is constructed from Perspex, with valves, wire, two graphite electrodes, a PEM, and a silicon sealant that can produce electricity and bacteria. Its construction involves taking the electrode and PEM and encasing it in a Plexiglas compartment we designed with valves and wires that connect to the electrode. We then make it airtight with the sealant. A flask (1 L capacity) will be the anode chamber, and a cylinder of Perspex (125 mL capacity) with two end pieces will be the cathode chamber. One end piece of the cylinder of Perspex has a hole fixed to the anode chamber. Both chambers will be physically separated by a proton exchange membrane with an interchange surface of 7 cm2. Each chamber contains a graphite electrode in either strip. The total accessible geometrical surface of the electrodes is intended to be 6.5 cm2. The electrodes will be attached to the external system using a copper wire with all exposed surfaces

sealed with non-conducting silicone.The parameters of several factors might be considered. The power density depends on various factors, including the following; electrode materials, electrode surface area, catalyst, organic exist and loading rate.

Preparation of microbial

1 liter of nutrient agar indicate suspending 20 g nutrient agar by heating in a boiling water bath or in a current of steam and autoclave (15 min at 121 °C) before pouring them into plates. Firstly, weigh 10–12 g nutrient agar for 1 L distilled water. Then slowly add the agar to 500 mL of cold demineralized water in a 1000 mL beaker with a gentle stirrer on a hotplate stirrer. Heat the mixture with a magnetic stirrer and boil for 15 minutes. Afterward, remove the beaker from the stirrer hotplate, retrieve the stirrer "flea" using a magnet, and cover the beaker (foil). Lastly, cool the nutrient agar to 50 °C and place the agar into clean Petri dishes. Another procedure for preparing nutrient agar involves heating it for approximately 15 mins before placing it in an autoclave at 121 °C.The Petri dishes are divided into four quarters and then heated up with wire loops until they turn bright red in colour. The dishes are then cooled for a few seconds. Afterward, the sample and bacteria are placed into the first quarter of Petri dishes that contain nutrient agar. Next, the steps are repeated using the second, third, and fourth quarters instead. Lastly, incubate the streak plate for 24 h at 37.1 °C.A drop of sterile distilled water is placed on the clean glass slide. A small sample of a colony is then dropped into the water and mixed gently. The emulsion is spread evenly on the surface of a glass slide to create a relatively thin and smooth layer. Allow the smear to dry by normal evaporation of water. Once the smear is completely dry, pass the slide over the flame of a Bunsen burner to heat-kill and fix the microorganism to the slide. Cover the smear with crystal violet for 20 seconds. Next, briefly wash off the stain with Lugol's iodine and cover the smear with Lugol's iodine for 30 seconds. Then pour off the iodine and wash thoroughly with acetone or alcohol. This step is critical. Thick smears will require more time than thin ones.
Decolorization occurs when the solvent flows colorlessly from the slide. Wash the acetone gently with running tap water. Cover the smear with safranin gently for a few seconds, and then blot and dry at room temperature. Wash the safranin gently for a few seconds, and then blot and dry at room temperature. The slide may be examined under a microscope. Results with purple or purplish-black bacteria indicate Gram-positive, whereas results with red or pink bacteria indicate Gram-negative. After examination under a microscope, the result obtained was Gram-positive (purple and purplish-black bacteria).

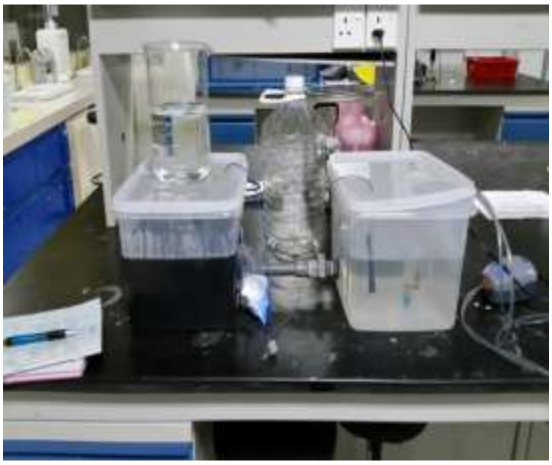


Figure1 MFC unit single system process set up

Results and Discussion

The leachate sample was collected from padang siding landfill, Perlis and tested in the laboratory for initial characterization. The data showed that the average leachate NH_3–N was 555 mg/L, COD was 3525 mg/L, BOD was 1131 mg/L, TSS was 183.53 mg/L, and pH value was 8.03. The characteristic result was slightly different from the results of Abu Amr and Aziz (2012). Therefore, it can be concluded that leachate composition and concentration depend on the landfill age (Barbusi et al., 2010). Our results depended on the characteristics of leachate for present works are tabulated in Table1.

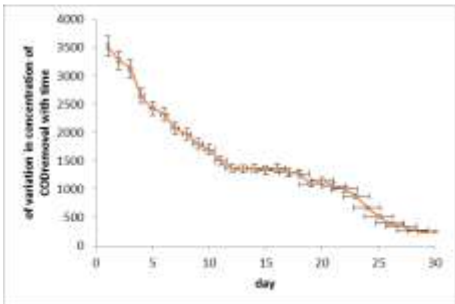
Table 1 Characteristics of leachate collected from Padang Siding Landfill, Perlis.

Parameter	Value
COD (mg/L)	3525
BOD (mg/L)	1131
pH	8.03
TSS (mg/L)	183.53

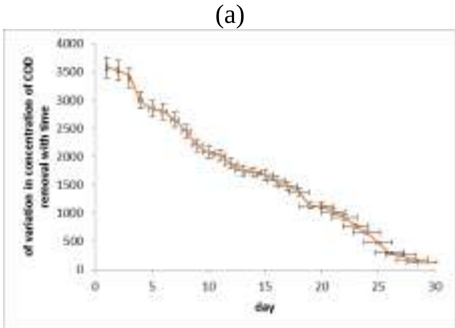
Results of Microbial Processing, the microbial culture and counting were successfully conducted. Puig et al. (2011) stated that MFC can produce voltage output. Based on voltage values from the beginning until the end of the treatment, the best result obtained from the zinc electrode was 0.761 mV, and the lowest was 0.492 mV. The highest voltage value for the activated carbon electrode was 0.260 mV, and the lowest was 0.038 mV. Meanwhile, the highest value for the black carbon electrode was 0.749 mV, and the lowest was 0.372 mV. Rahimnejad et al. (2015) likewise showed that granular-activated carbon has a high degree of micro-porosity and catalytic activities and becomes cheaper with increased conductivity.

COD Removal With MFC Dynamic Mode

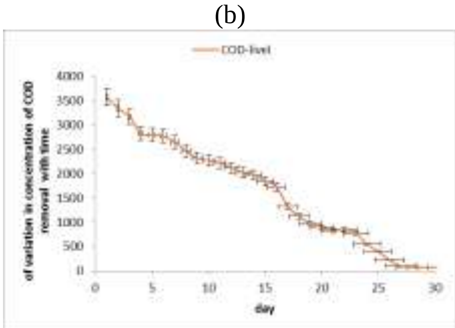
The different graphs show the results of different electrodes used in an MFC reactor over a 30-days period. The COD concentration of the black carbon electrodedropped dramatically from 3525 mg/L on day 16 to 825 mg/L on day 21. Afterward, the concentration decreased on day 27 and remained steadily at 175mg/l. The COD concentration for active carbon started to decrease from 3525 mg/L on the last day result 125mg/l with a removal percentage of 96.45%. Lastly, the COD concentration for the zinc electrode started to decrease gradually from 3525 mg/L day 18 to 1600 mg/L and remained unchanged at 205mg/L until the end of the process because bacteria had died. Several studies have shown that leachate in the stabilized stage is difficult to degrade further biologically when COD is low (Aziz et al., 2010).



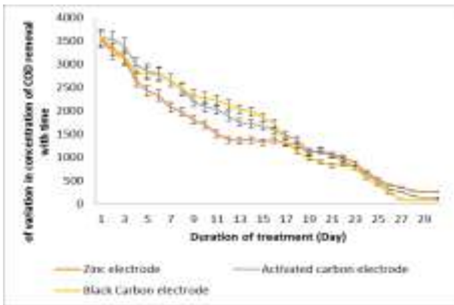
(a)



(b)



(c)



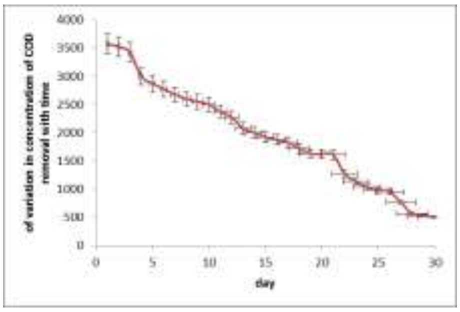
(d)

Figure 4: (a) COD removal by zinc electrode via dynamic system (b) COD removal by activated carbon electrode via dynamic system (c) COD removal by carbon black electrode via dynamic system (d) Profile of COD versus day of the MFC treatment of leachate by using different electrodes in dynamic state.

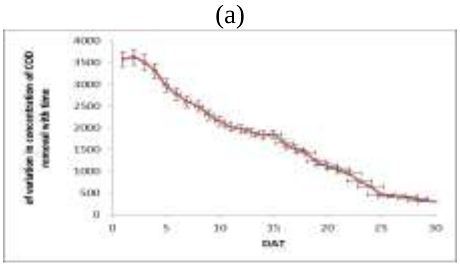
Figure 4(a) shows the graph of COD versus the duration of treatment (Day and variation in concentration of COD removal. Results show varying trends for the different types of electrodes. The COD concentration for the zinc electrode gradually decreased from 3525 mg/L to 250 mg/L with 92.91% of removal percentage it then remained unchanged until the end of the process because bacteria had died. Several studies have shown that leachate in the stabilized stage is difficult to degrade further biologically when COD concentration is low. A similar result was reported by Aziz et al. (2010).Figure 4 (b) shows the efficiency of the active carbon electrode in decreasing COD, variation in concentration of COD removal with time. The COD concentration started to decrease from 3525 mg/l on Day 18, and then remained stable on days 19 and 20. Afterward, the COD concentration remained stable at 125 mg/L on days 29 and 30 with 96.45%.. Figure 4 (c) shows the efficiency of the carbon black electrode in decreasing COD. The COD concentration started to decrease dramatically from 3525 mg/L on day 1600 to 1025 mg/L on day 21. It then decreased down to 175mg/l at the end of the process. Figure (d) shows a comparison of the performance of the different electrodes. The COD concentration decreased dramatically from 3525 mg/L on day 16 to 1600 mg/L on day 21, and then increased to 1025 mg/L on day 22 for the black carbon electrode. Next, the concentration decreased again on day 27 and remained stable 175mg/l. The COD concentration of activated carbon decreased from 3525 mg/L on day 18. The result remained stable on days 19 and 20 and decrease to 125mg/l.However, a static state occurred on days 29 and 30, where the COD concentration was 125 mg/L. Lastly, the COD concentration for the zinc electrode started to decrease gradually from 3525 mg/L on day 18 to 1600 mg/L and finally reached 250mg/l. The concentration remained stable until the end of the process because bacteria had died. Several studies have shown that leachate in the stabilized stage is difficult to degrade further biologically when COD concentration is low.

COD Removal with MFC Static Operation Mode

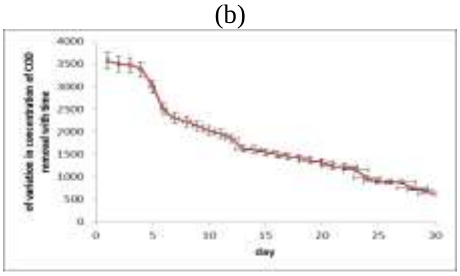
Figure 5 (a) shows the graph of COD versus the duration of treatment (Day) in static mode operation of the MFC for the removal of COD. The concentration started to drop dramatically from 3525mg/L on day 4 to 2125 mg/L on day 9. Finally, the graph of the zinc electrode shows that COD concentration decreased from 3525 mg/L on day 1 to 1725 mg/L on day 18. The result remained steady at 1625 mg/L on days 19 and 20 and decreased gradually until the end of the process. Leachate parameters vary with the age of the landfill. For instance, young leachate that is one to two years in age is characterized by high organic fraction of substances with relatively low molecular weight, such as volatile organic acids, and high COD.



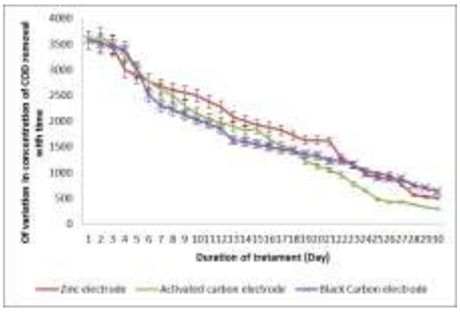
(a)



(b)



(c)



(d)

Figure 5 : (a) COD removal by zinc electrode via static system (b) COD removal by activated carbon electrode via static system (c) COD removal by black carbon electrode via static system (d) Profile of COD versus day of the MFC treatment of leachate by using different electrodes in static state.

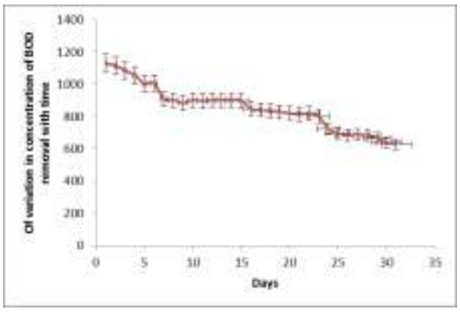
Figure 5(a) shows the efficiency of the zinc electrode in the MFC reactor in removing COD in static mode. The COD concentration gradually decreased in a linear fashion from 3525 mg/L on day 1 to 503 mg/L on day 30. Carbon is a popular substance in the treatment of leachate. figure 5b shows that the efficiency of activated carbon in removing leachate is impressive because almost all COD was removed. The removal rate from days 1 to 3 no difference and the removal rate later on remained very efficient. The removal rate was exceptionally high at the beginning because the amount of bacteria supporting the reaction was also high. Thereafter, the amount of bacteria gradually decreased with the passage of time but still allowed for a constant rate of removal. The removal from was 3525mg/l until 300mg/l with 91.49%. When using the black carbon electrode, the COD concentration decreased smoothly from 1550 mg/L on day 15 to 625 mg/L on day 30. When using the active carbon electrode, the COD concentration decreased slowly from 3525 mg/L on day 1 to 300 mg/L on day 30, as shown in Figure 5c compared to the black carbon.Figure 5d shows the graph of COD versus the duration of treatment (Day) in static state. The COD concentration started to drop dramatically from 3325 mg/L on day 4 to 2125 mg/L on day 9. The COD concentration when using the black carbon electrode decreased smoothly from 1550 mg/L on day 15 to 625 mg/L on day 30. The COD concentration when using the active carbon electrode decreased slowly from 3575 mg/L on day 1 to 300 mg/L on day 30.

Finally, the graph of the zinc electrode shows that COD concentration decreased smoothly from 3525 mg/L on day 1 to 1725 mg/L on day 18. The COD concentration then stabilized to 1625 mg/L on days 19 and 20 and decreased slowly until the end of the process. Leachate parameters commonly vary depending on the age of a landfill.

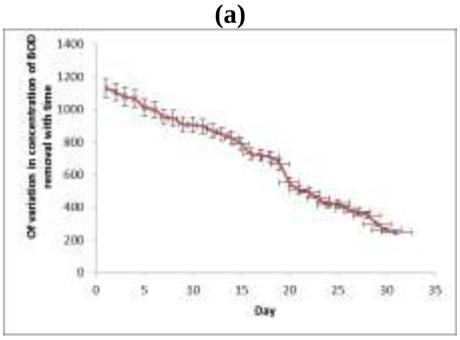
For instance, young leachate that is one or two years old has a high organic fraction of substances with relatively low molecular weight, such as volatile organic acids, and high COD (Umar et al., 2010). On the other hand, leachate that is older than 10 years is characterized by a relatively low COD (Li et al., 2010).

BOD removal with MFC using dynamic operation mode

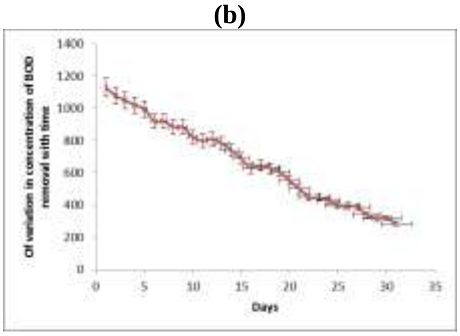
Figure 6(a) shows the graph of BOD versus duration of treatment (Day). The different types of electrodes produced varied results. The BOD concentration for the zinc electrode started to decrease gradually from 1131 mg/L on day 1, it then reduced to 670 mg/L in day 24. Where gradually reduced to 627mg/l with 44.56%. Finally, It then remained unchanged until the end of the process because bacteria had died. Several studies have shown that leachate in the stabilized stage is difficult to degrade further biologically when BOD concentration is low.



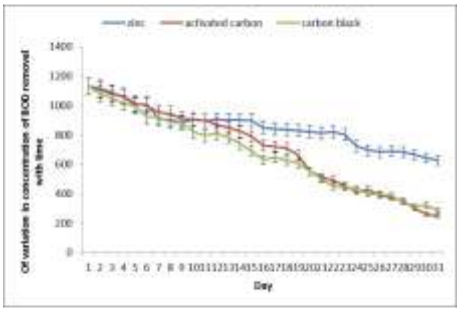
(a)



(b)



(c)



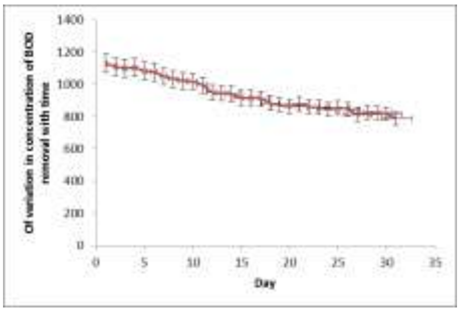
(d)

Figure 6 :(a) BOD removal by zinc electrode via dynamic system (b)BOD removal by activated carbon electrode via dynamic system (c) BOD removal by black carbon electrode via dynamic system (d) The Profile of BOD versus day of the MFC treatment of leachate by using three different electrodes in dynamic state.

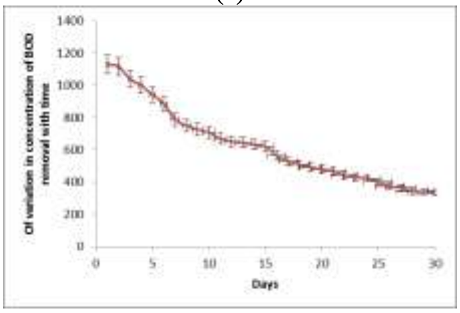
Figure 6b shows the performance of the active carbon electrode in removing BOD. The BOD concentration started to decrease from 1131 mg/L on day 1, it continues to decrease until it reached day 19. From here it drastically decreases to ~570mg/l. The BOD continues to decrease from day 19 until last day. The removal was 249mg/l with 77.98%. Figure 6c shows the rate of BOD removal of the carbon black electrode. The BOD concentration started to drop dramatically from 1131 mg/L from the day 1 and continue linearly throughout the treatment period, at the end of the treatment period the remaining BOD concentration was 285mg/l with 74.80%. Figure 6d shows the comparison of the performance of the three electrode namely: zinc, activated carbon and carbon black. All the three electrode have shown capability of removing the BOD but activated carbon and carbon black shown extreme performance. With black carbon the removal of BOD was 285mg/l with 74.80%. With activated carbon removing high it remained only 249 with 77.98% after treatment.

BOD removal with MFC using static operation mode

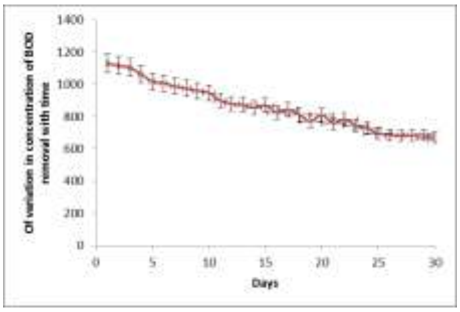
The following shows the graph of BOD versus duration of treatment (Day) of the MFC in static mode. BOD concentration started to drop dramatically from 1131 mg/L on day 5 to 1077 mg/L,1017 on day 9. The graph of the zinc electrode shows a smooth decrease of BOD concentration from 575 mg/L on day 1 to 873 mg/L on day 18. The BOD concentration remained steady at 1131 mg/L on days 14 and 16 and decreased slowly until the end of the process. Leachate parameters commonly vary depending on the age of a landfill. For instance, young leachate that is one to two years old usually contains a high organic fraction of substances with relatively low molecular weight, such as volatile organic acids, and a high BOD.



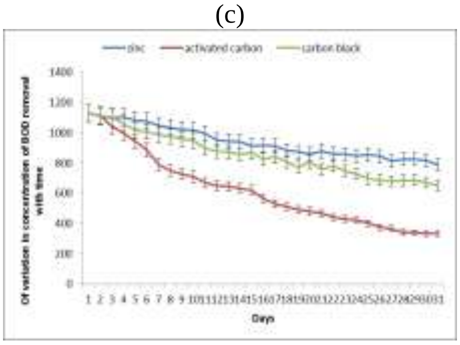
(a)



(b)



(c)



(d)

Figure 7: (a) BOD removal by zinc electrode via MFC in static mode (b) BOD removal by activated carbon electrode via MFC static system (c) BOD removal by carbon black electrode via MFC static system (d) the Profile of BOD versus day of the MFC treatment of leachate by using three different electrodes in static state.

Figure 7a shows that the efficiency of the zinc electrode in removing BOD in static mode is impressive. The BOD concentration decreased from 1131 mg/L on day 1 to 951 mg/L on day 11. However, the decrease in BOD stabilized at 846 mg/L on days 23 and 24 and decreased slowly until the end of the process to approximately 789 mg/L with 30.24%. The removal of the leachate parameters such as BOD was impressive, though the rate of removal depended on several factors. Given that the MFC rate was low and in static mode, the rate of BOD removal was also expected to be low. Furthermore, the ion exchange rate is restricted, and young leachate of one to two years is characterized by a high organic fraction of substances with relatively low molecular weight, such as volatile organic acids, and a high BOD reaction. Figure 7b shows the graph of BOD versus duration of treatment (Day) of the activated carbon electrode in the MFC in static mode. The BOD concentration gradually decreased and it continue linearly from the first day with 1131 mg/l until its reached day 27 with 342mg/l. The removal rate became low from there until the last day. Finally, the remaining BOD concentration was

Figure 7c shows the graph of BOD versus duration of treatment (Day) of the carbon black electrode in the MFC in static mode. The process maintained a constant reduction in BOD. The BOD concentration gradually decreased from 1131 mg/L to ~651 mg/L with 42.44% on day 30. The figure 7d compared the removal of the BOD concentration by the three anodes electrode with static mode operation. As can seen here, all the three electrode were able to remove considerable amount of BOD. However. Activated carbon removed the high BOD concentration. The removal of the zinc was from 1131mg/l to 789mg/l, while the activated carbon removed from 1131mg/l to 333mg/l and the black carbon removed from 1131mg/l to 651mg/l.

TSS Removal with MFC

Figure 8 shows the ability of the different electrodes to remove TSS. The TSS reductions were greater in static mode than in dynamic mode (~42.20 %). For the removal of the TSS with an initial concentration of 183.53mg/Lwas shown in Figure 4.27. The TSS was removed by zinc electrode with dynamic and static system to 125mg/l (31.9% removal and to 83mg/l (54.80% removal) respectively. For activated with dynamic and static removed from 183.53mg/l to 106mg/l with 42.20% and from 183.53 mg/l to 79 mg/l with 56.9% respectively and the TSS removal by black carbon using dynamic and static operation mode from 183.53mg/ to 98 mg/l with 46.6% and 183.53mg/l to 72mg/l with 60.7%.

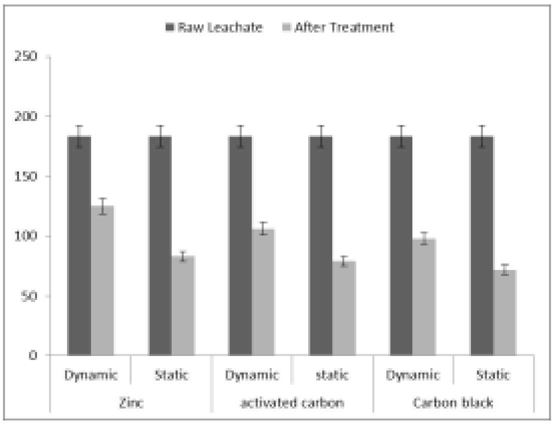


Figure 8: TSS removal by zinc, activated carbon, and carbon black electrode via dynamic and static systems

Conclusion

This study demonstrated the ability to combine two difference methods into single effective method for leachate treatment. The biochemical and physiochemical were combined to develop highly effective leachate treatment. The biochemical treatment was done through MFC to treat leachate as well as generate electricity. Two MFC operation modes were used in this study: dynamic and static. These modes were run to complement each other. Both modes were tested with different electrodes: zinc, active carbon, and black carbon. Due to the MFC could not remove all components, the Fenton process was introduced to complement this shortcoming. The leachate of Padang Siding Landfill, Perlis had a pH of ~8.03, an average COD of ~3525 mg/L, an average BOD of ~1131 mg/L, an average ammonia content of 555mg/L and average TSS of 183.53mg/l. In conclusion, leachate from Padang Siding Landfill, Perlis was successfully reduced after being treated by the MFC and Fenton processes. The final values of the, COD, BOD and TSS, were, 125 mg/l (96.45% removal), 249mg/l (77.98 % removal) and 106mg/l (42.20% removal) respectively.

References

1) Adhikari, B., Dahal, K. R., &Khanal, S. N. (2014).A Review of Factors Affecting the Composition of Municipal Solid Waste Landfill Leachate, 3(5), 273–281.
2) Araceli Gonzalez del Campo, Jose F. Perez , Pablo Canizares, Manuel A. Rodrigo, Francisco J. Fernandez, Justo Lobato. Study of a photosynthetic MFC for energy recovery from synthetic industrial fruit juice wastewater, International Journal of Hydrogen Energy 39 (2014) 21828-21836
3) Aziz, H. A., O. M. Othman, et al. (2013). "The performance of Electro-Fenton oxidation in the removal of coliform bacteria from landfill leachate." Waste Management Vol 6(2) 423-430
4) Aziz, S. Q., H. A. Aziz, et al. (2011). "Landfill leachate treatment using powdered activated carbon augmented sequencing batch reactor (SBR) process Optimization by response surface methodology." Journal of Hazardous Materials Vol 4(3) 33-44
5) Guodong Zhang, Yan Jiao, Duu-Jong Lee (2015) A lab-scale anoxic/oxic-bioelectrochemical reactor for leachate Treatments, Bioresource Technology 186 (2015) 97–105
6) Handbook of Environment and Waste Management.(2012). Air and Water Pollution Control. Retrieved May 22, 2015,
7) HaritiBouhezila, F., M., et al. (2011). "Treatment of the OUED SMAR town landfill leachate by an electrochemical reactor." Desalination. Vol 6(2) 23-30
8) Jayesh M. Sonawane, Enrico Marsili, Prakash Chandra Ghosh (2014) Treatment of domestic and distillery wastewater in high surface microbial fuel cells, International Journal of Hydrogen Energy 39 (2014), 21819-21827
9) Jiao Zhang, G.D., Zhao, Q.L., , Y., Zhang, J.N., Jiang, J.Q., Ren, N.Q., Kim, B.H., 2011. Improved performance of microbial fuel cell using combination biocathode of graphite fiber brush and graphite granules. J. Power Sources 196, 6036–6041.
10) Karmakar, S., Kundu, K., &Kundu, S. (2010). Design and development of Microbial Fuel Cell.Current Research. Technology and Education Topics in Applied Microbiology and Microbial Biotechnology, 1029-1034.
11) Kolhe and Pawar (2011)Physico-chemical analysis of effluents from dairy industry Recent Research in Science and Technology, 3(5): 29-32
12) Krishnadas Ganesh, Jenna R. Jambeck (2013) Treatment of landfill leachate using microbial fuel cells: Alternative anodes and semi-continuous operation, Bioresource Technology 139, 383–387
13) PalaniandyAdlan, M. N., P., et al. (2011). "Optimization of coagulation and dissolved air flotation (DAF) treatment of semi-aerobic landfill leachate using response surface methodology (RSM)." Desalination Vol 2(3) 33-42
14) Prasad Verma, S, B. & Mishra, I.M. (2010).Pretreatment of petrochemical wastewater by coagulation and flocculation and the sludge characteristics. Journal of Hazardous Materials, 178, pp. 1055-1064.
15) Puig, S. et al., (2011).Microbial fuel cell application in landfill leachate treatment. Journal of Hazardous Materials, 185(2-3), 763–767.
16) Qixing Wei Li, Zhou, and Tao Hua, (2010) Removal of Organic Matter from Landfill Leachate by Advanced Oxidation Processes: A Review, International Journal of Chemical Engineering, Vol. (2010), pp. 1-10
17) R.H. Kettunen, T.H. Hoilijoki& J.A. Rintala.(2009) Anaerobic and sequential anaerobic-aerobic treatments of industrial and municipal landfill leachate at low temperatures.Bioresour.Technol, 58, 40-41.
18) Raghab, S.M., Abd El Meguid, A.M. & Hegazi, H. a., (2013).Treatment of leachate from municipal solid waste landfill. HBRC Journal, 9(2), 187–192.
19) Rahimnejad, M., Adhami, A., Darvari, S., Zirepour, A., & Oh, S.-E. (2015). Microbial fuel cell as new technology for bioelectricity generation: A review. Alexandria Engineering Journal, 54(3), 745–756.
20) Ringeisen BR, Henderson E, Wu PK, Pietron J, Ray R, Little B & Jones-Meehan JM.(2006). High power density from a miniature microbial fuel cell using Shewanellaoneidensis DSP10. Environ. Sci Technol,40(80), 2629-2634.
21) Sani, a. et al., (2014) The influence of pH on the removal of ammonia from a scheduled waste landfill leachate. JurnalTeknologi (Sciences and Engineering), 68(5),.25–28.
22) Seow- Wee (2012) New Perspective of Integrated Solid Waste Management in Malaysia. In Proceeding 3rd International Conference on Human Habitat &

Environment in the Malay World, 19-20 Jun 2012, UKM, Bangi
23) Serra Puig, S., M., Coma, M., Cabré, M., Balaguer, M.D., Colprim, J., (2011) Microbial fuel cell application in landfill leachate treatment. J. Hazard. Mater. 185, 763–767.
24) Solid Waste Management and Public Management Cleansing Corporation (2011) Implementation of Solid Waste and Public Cleansing Management Act (Act 672), Annual Report 2011 (Chapter 4). Kuala Lumpur: Solid Waste and Public Cleansing Management Corporation
25) Teixeira, Cortez, S., P. et al. (2011). "Evaluation of Fenton and ozone-based advanced oxidation processes as mature landfill leachate pre-treatments." Journal of Environmental Management. Vol 6(7) 333-339
26) TizaouiZahrim, A.Y, C. &Hilal, N. (2011). Coagulation with polymers for nanofiltration pre-treatment of highly concentrated dyes: A review. Desalination, 266, pp. 1-16.
27) Tong, Zhang, B., Liu, Y., S., Zheng, M., Zhao, Y., Tian, C., Feng, C. (2014).Enhancement of bacterial denitrification for nitrate removal in groundwater with electrical stimulation from microbial fuel cells. Journal of Power Sources, 268, 423-429
28) Wang, Zhu, F., W., Zhang, X., Tao, G., 2011.Electricity generation in a membraneless microbial fuel cell with down-flow feeding onto the cathode.Bioresour.Technol. 102, 7324–7328.
29) Wein, Y.X, Li, Y.F. & Ye, Z.F. (2010).Enhancement of removal efficiency of ammonia nitrogen in sequencing batch reactor using natural zeolite. Environ Earth Sci, 60, pp. 1407-1413.
30) Woo, J.H. Im, H.J M.W. Choi, K.B. Han, C.W. Kim. (2001) Simultaneous organic and nitrogen removal from municipal landfill leachate using an anaerobic-aerobic system. Water Res, 35, 2403-2410.
31) Wu, Y., Zhou, S., Qin, F., Ye, X., & Zheng, K. (2010). Modelling physical and oxidative removal properties of Fenton process for treatment of landfill leachate using response surface methodology (RSM). Journal of Hazardous Materials, 180(1-3), 456–465.
32) Young Li. Hon et al., (2010) Microbial fuel cells using natural pyrrhotite as the cathodic heterogeneous Fenton catalyst towards the degradation of biorefractory organics in landfill leachate. Electrochem.Commun. 12 (7), 944–947.
33) Zemmouri, H, Drouiche, M, Sayeh, A, Lounici, H. &Mameri, N. (2012).Coagulation-flocculation test of keddara's water dam using chitosan and sulphate aluminium.Proceddia Engineering, 33, pp. 254-260.
34) Zhang, Q.-Q.et al., (2013) Investigation on characteristics of leachate and concentrated leachate in the landfill leachate treatment plnts. Waste Managemnet, 33(11), 2277–2286.
35) Zhao, G.D. Zhang, Q.L., Jiao, Y., Wang, K., Lee, D.J., Ren, N.Q., 2012. Biocathode microbial fuel cell for efficient electricity recovery from dairy manure.Biosens.Bioelectron. 31, 537–543.