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Detection of Landfill Gas in Leachate Pipe and Pond of a Semi-Aerobic Landfill

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Landfills provide very simple and affordable means of solid waste disposal, hence they are widely accepted and adopted as means for disposing off solid waste. Nonetheless, landfills pose some negative effects to the environment as a result of their production of leachate and emission of greenhouse gases. Predominant in recent landfill design and construction, aerobic or semi aerobic processes are allowed to occur within the landfill in order to hasten up the decomposition of the biodegradables in the solid waste, as well as to combat the problem of odour generation from the landfills. The semi aerobic system of landfill design is widely used in Malaysia. In this study, characterization of the various parameters which represent the organic material contained in landfill leachate, which are basically the COD and BOD_5, was done. Gas sampling at the end of leachate pipes and on leachate pond surfaces were also carried out. Gas sampling bag was used to collect gas samples from the surface of leachate ponds, while a simple water displacement method was used to collect gas samples at the end of leachate pipes. Leachate samples were also collected from two different leachate ponds equalization pond and intermittently aerated pond in the semi-aerobic landfill, their COD and BOD_5 values were measured and found to be in the range of 15,000 - 16,900 mg/L and 6,821 - 8,009 mg/L and 1,360 - 1,600 mg/L and 198 - 250 mg/L. The concentration of methane gas captured at the end of the leachate pipe was about 12 %, while the methane gas concentration escaping to the environment from the surface of the leachate pond was about 9 %. Improved form of leachate collection pipes is highly recommended for semi aerobic landfills. In-situ treatment for landfill leachate from semi aerobic landfills is highly encouraged in order to reduce the organic load of the leachate collected in leachate ponds.

1. Introduction

Several factors, such as the constant increase in population, social civilization growth, technological advancements, changes in habit in terms of productivity and consumption, increasingly affluent lifestyles and use of resources, continued commercial and industrial development have been accompanied by the rapid generation of municipal and industrial solid wastes globally (Bashir et al., 2010a). Due to its simplicity in design and operation, as well as cost implication, sanitary landfills are still favoured in terms of solid waste disposal as compared to other techniques used in solid waste handling such as composting and incineration (Davis and Cornwell, 2008). Nonetheless, there is the need for constant critical monitoring of the environment amid the design, construction and operation of landfills. Post closure monitoring of landfill sites is also imminent, due to their leachate generation tendency as well as gas emission from landfill surfaces which can actually be sources of pollution to the environment if not properly controlled. In order to stem leachate infiltration into surrounding ground water which pollutes the environment, recent landfill designs are fortified with engineered composite (geomembrane) liners and leachate collection systems (Wiszniowski et al., 2007). Current trends in landfill design allows aerobic or semi aerobic processes to take place within the landfill in order to speed up the degradation process, reduce odour and generate leachate with less COD and BOD_5 values, which represent the organic strength of the leachate. In Malaysia, the semi aerobic system of landfill design is adopted (Chong et al., 2005). However, leachates

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generated from semi aerobic landfills in Malaysia have been reported to have COD values as high as 16,100 mg/L (bin Ghazali et al., 2014). Leachates are a product of the percolation of precipitation, surface run off, irrigation water, initial water contained in the solid wastes and could also be as a result of biochemical, chemical and physical reactions (Foul et al., 2009). Landfill leachate is characterized by high organic matter content, which is usually measured as COD and BOD_5, ammonia, halogenated hydrocarbons, phenols and a significant amount of heavy metals (Aziz et al., 2009). Landfill leachate undergoes successive stages such as aerobic, acetogenic, methanogenic and stabilization stage, which are predominantly determined by the landfill age. Landfills are referred to as young landfills when they are less than five years old, characterized by high concentrations of COD and BOD_5, relatively high amount of ammonia, nitrogen, high BOD_5/COD ratio and pH values less than 6.5. While landfills above 10 y are said to be old, mature or stabilized landfills, having lower COD, BOD_5, with BOD_5/COD ratios usually less than 0.3 and large amount of refractory contaminants (Wang et al., 2009).
The organic fractions of municipal solid waste decompose under anaerobic conditions in landfills thereby generating landfill gases such as methane and carbon dioxide which are greenhouse gases and have adverse negative impact on the environment and less volumes of other gases (Abbasi et al., 2012). bin Ghazali et al. (2014), reported that the following gases can be detected in landfills; methane gas, carbon dioxide, ammonia, oxygen, nitrogen, hydrogen, carbon monoxide, non-methane organic compounds and sulphides.
The volume of CH_4 and CO_2 as landfill gases ranges between 55 - 60 % and 40 - 45 %, with CH_4 having a potency that is 21 times greater than that of CO_2, to cause global warming (Ayalon and Avnimelech, 2009). The current mode of landfill design and operation, allows landfill gases to be recovered from the solid waste matrix via gas vents and only about 50 % of the total theoretical gas volume is being recovered from the actual generated volume of landfill gas, due to escape of landfill gases from leachate pipes, landfill covers, gas venting systems and from the surface of leachate ponds (Spokas et al., 2006).
Leachate collected from semi aerobic landfill leachate ponds are also characterized by a high concentration of organic matter content, which connotes a strong potency for methane gas production in the leachate ponds (Aziz et al., 2010). Recovered methane gas from landfills have been used as an alternative source of energy generation over the years (Bolan et al., 2013), especially as there is a global environmental concern related to the use of fossil fuels as a source of energy (di Cristofaro et al., 2014).
The main objective of this current study is to determine the constituent composition of greenhouse gases detected from selected points such as; the end of leachate pipe and the surface of leachate pond, of a semi aerobic landfill. The organic matter content of two different leachate ponds were measured in form of BOD_5 and COD, within a period of three months in order to ascertain the organic strength of the leachate and its potency to generate methane gas under anaerobic condition. Other physico-chemical parameters such as pH, EC, colour and turbidity were also measured.

2. Sampling and method

The leachate samples were collected from two different leachate ponds (equalization and intermittently aerated ponds) from a semi aerobic sanitary landfill in Selangor state of Malaysia. Leachate from all the pumps in the landfill are mixed and collected in the equalization pond, while the aerated pond contains leachate undergoing the biological treatment process. Sample collection at the landfill site was done between August and October 2014 and were immediately sent to the laboratory where they were preserved in a cold room with temperature of 4 ºC before they were used for the experiment so as to eliminate the possibility of biological and chemical reactions taking place, thereby distorting the original characteristics of the leachate before measurement is done. Gas samples were collected from the end of leachate pipe and the surface of open leachate collection ponds. Gas sampling from the end of the leachate pipe was done by water displacement method with the aid of a 500 mL conical flask that contained acidified water. The acidified water contained in the flask was to prevent any reaction between CO_2 gas collected from the leachate pipe and the water, in order to obtain the actual volume of gas collected. A 6 mm wide colourless silicone tube fastened with a valve was connected to a metal pipe that drove through the cork of the conical flask, served as gas inlet from the leachate pipe. It was held in place with the aid of a plastic band, so that gas coming out alongside the leachate from the pipe can be collected. Another metal pipe connected to a silicone tube was used as outlet for the displaced water. The gas trapped in the conical flask is characterized to ascertain its composition (Figure 1). Gas sampling from the surface of the leachate pond was carried out with the aid of a 3 L Tedlar gas sampling bag. A funnel with a base width of 8 inches was fastened at its end with a cork stopper and properly sealed with a laboratory plastic film to prevent leakage. A metal pipe connected to a colourless silicone tube with a valve, was connected to the gas bag as shown in (Figure 2) was used as gas inlet. The metal pipe was driven through the cork stopper. The funnel was placed over portions of the leachate collection ponds from where gas was seen bubbling (Figure 3), gas pressure was allowed to build up within the funnel for 24 h and then slowly filled the gas sampling bag. The collected gas was characterized to ascertain its constituent composition.

Figure 1: Gas sample collection from the end of a leachate pipe at the semi-aerobic sanitary landfill site.

3. Results and Discussion

Table 1 shows the characteristics of the leachate, as well as the range and the average values for all the parameters considered for the two different leachate ponds at the semi-aerobic sanitary landfill.

3.1 pH

The pH values for equalization pond (EQ) and the intermittently aerated pond both varied at 7.80 - 8.30 and 8.28 - 8.90. The pH results are found to be consistent with those reported by previous researchers, 8.05 - 8.35 (Aziz et. al., 2010) and 8.3 – 9.10 (Bashir et al., 2010b), who recorded pH values with similar range from a stabilized semi-aerobic landfill. However, the measured pH values fell within the permissible limit (5.5 - 9.0) set in the Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009, Malaysian Environmental Quality Act 1974 - Act 127 (Aziz et al., 2010).

3.2 Chemical Oxygen Demand (COD)

The COD values for the leachate samples collected from the two different leachate ponds ranged between 15,000-16,900 mg/L and 6,821-8,009 mg/L for EQ1 pond and the intermittently aerated pond, while their average values were 16,100 mg/L and 7613 mg/L respectively. The high COD values measured from the leachate samples indicate the high organic matter content in the leachate, which can further be degraded under anaerobic condition to produce methane gas. The values obtained are consistent with those recorded by (bin Ghazali et al., 2014).

3.3 Biological Oxygen Demand (BOD5)

In determining the strength of organic pollutant in both surface water and wastewater, BOD5 is the parameter that is mostly measured. The BOD5 of a sample is determined by measuring the quantity of dissolved oxygen that is needed by organisms in water to break down the organic materials present in the water, at a particular temperature, over a fixed duration. The equalization pond had the highest value of BOD5 of 3,200 mg/L, while that of the intermittently aerated pond was 1,510 mg/L. High BOD5 values further indicate the presence of large amount of organic materials in the leachate from the landfill. These organics, under anaerobic condition as seen in Figure 3, further degrade producing methane as a greenhouse gas which escapes into the environment, thereby polluting it with the potency of causing global warming. However, higher BOD5 values ranging between 99-13,900 mg/L have been recorded by (Canziani et al., 2006).

Table 1: Characteristics of raw leachate from landfill site during August to October 2014

No.	Parameter (unit)	Equalization pond		Intermittently aerated pond	
		Range	Mean	Range	Mean
1	pH	7.80 - 8.30	8.00	8.28 - 8.90	8.73
2	COD (mg/L)	15,000 - 16,900	16,100	6,821 - 8,009	7,613
3	BOD_5 (mg/L)	2,910 - 3,370	3,200	1,360 - 1,600	1,510
4	EC (Ms/cm)	17.3 - 24.2	21.9	33.2 - 40.35	37.0
5	Turbidity (NTU)	500 - 905	735	808 - 1,107	940
6	Colour (PtCo)	2,623 - 3,803	3,318	2,420 - 4,495	3,449

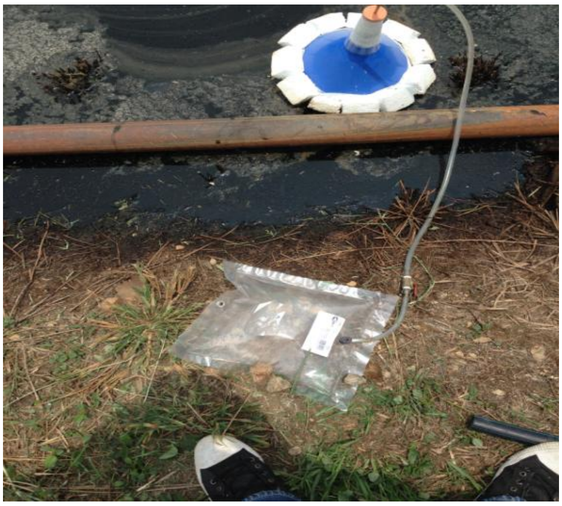

Figure 2: Set up of apparatus used for gas sampling at the leachate collection pond surface

Figure 3: Gas bubbles in leachate pond from which gas sampling was done

3.3 Other physical properties of leachate samples

Other physical parameters of the leachate samples collected that were measured includes electrical conductivity (EC), turbidity and colour and their measured values for the equalization pond (EQ) and the intermittently aerated pond ranged between 17.3 - 24.2 and 33.2 - 40.35 Ms/cm, 500 - 905 and 808 - 1,107 NTU and 2,623 - 3,803 and 2,420 - 4,495 PtCo. The high concentration of colour recorded from the landfill leachate is as a result of high organic substances present in the leachate (Aziz et al., 2007). However, greater ranges of 5,330 - 5,760 was recorded by (Bashir et al., 2010b) and 3,790 - 4,010 by (Mohajeri et al., 2010).

4. Gas detected at the end of leachate pipe

The gas samples collected from both the end of a leachate pipe and the surface of the leachate collection pond, were analysed using a GC-2010 Shimadzu gas chromatography machine and their results represent only the constituent concentration of methane and carbon dioxide gas. At a retention time of 1.4141 min, the methane gas concentration was found to be approximately 12 % at a peak value of 6,010 of relative intensity. The peak area was 13,100 mm^2. The concentration of CO_2 was about 28 % at 1.7554 min of retention time. The value of the peak area was given to be 29,021 mm^2, having a relative intensity of 10,608. The concentration of carbon dioxide gas was observed to be more than that of methane, which could have resulted from the presence of oxygen/air in the leachate pipe, especially as the diameter of the leachate pipe is large. The values recorded in this study are similar to those recorded in previous studies (bin Ghazali et al., 2014).

5. Gas collected from leachate pond

The GC-2010 Shimadzu gas chromatography machine was also used to analyse the constituent concentration of gases present in the sample collected from the surface of the leachate collection pond. At the retention time of 1.4237 min, the methane gas concentration was recorded to be approximately 9 % at the peak value of 3,933 of relative intensity. The peak area was 7,052 mm^2. The concentration of carbon dioxide was 25 % at 1.8030 min of retention time. The value of the peak area was given to be 32,568 mm^2, having a relative intensity of 7,887. The landfill can be said to be a stabilized semi-aerobic landfill considering the pH values shown in Table 1 and at pH values of such methanogenesis could be said to be occurring (Sapari et al., 2013), where more methane gas is produced by the landfill, although more carbon dioxide was recorded to be present in the sample collected from the leachate pond, this could be due to the presence of oxygen in the surface of the leachate pond.

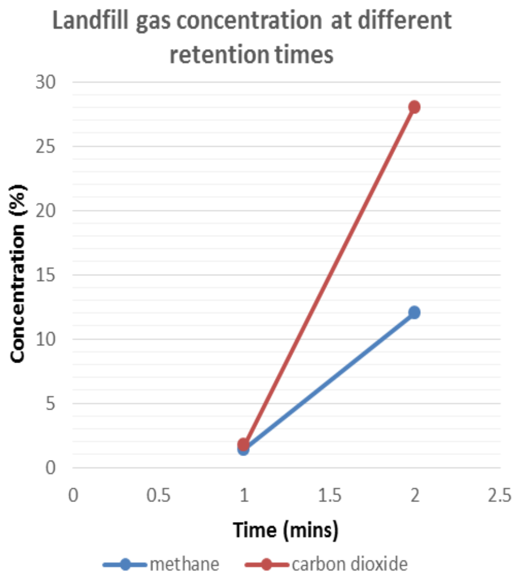

Figure 4: Plot showing the concentration of CH_4 and CO_2 gases for sample collected at the end of the leachate pipe

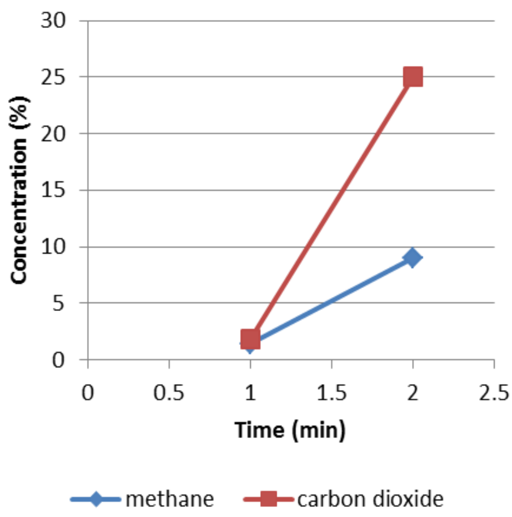

Figure 5: Plot showing the concentration of CH_4 and CO_2 gases from sample collected at the surface of leachate collection pond

6. Conclusion

Semi-aerobic system of landfill design and operation which has been widely accepted by many for the disposal of municipal solid wastes, allows the escape of greenhouse gases such as methane and carbon dioxide into the environment via leachate collection pipes and leachate collection ponds. Methane and carbon dioxide gases with concentrations up to 12 and 28 %, were observed to escape from the end of leachate pipes into the environment. From the surface of leachate collection ponds the gas concentrations were found to be 9 % and 25 % for methane and carbon dioxide gases. In-situ treatment of leachate is highly recommended for semi-aerobic landfills, in order to reduce the strength of the organic substances contained in the leachate before it is collected at the leachate ponds via the leachate pipes. Better design of leachate collection pipes is also recommended, so as to reduce the amount of landfill gas that escape through the end of leachate collection pipes.

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