COMPARISON OF METHANE OXIDATION POTENTIAL BETWEEN COMPOST AND BLACK SOIL AT JERAM LANDFILL

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ABSTRACT Landfills are significant sources of atmospheric methane (CH_4) that contributes to greenhouse gas effect, and therefore there is a need to reduce the CH_4 emissions from landfills. Small scale landfills in Malaysia and other developing countries generally do not generate enough CH_4 for energy harvest. CH_4 emission can be reduced by means of microbial oxidation enhanced by biologically engineered landfill covers. This is a promising cost-effective technology to enhance biological oxidation of CH_4 in small scale landfills. The selection of suitable materials represents one of the key issues in constructing biotic CH_4 oxidation systems. Composts and black soil have been proven to support CH_4 oxidation and they represent a low cost alternative to other sandy or humic-rich soil substrate. This study was carried out to investigate the CH_4 oxidizing capacity of compost and black soil under field conditions. Experiments with different flow rates of landfill gas have shown that compost has a higher oxidation capacity compared to black soil. At 100 cm of cover height and flow rate of 300 ml per minute, black soil has an oxidation capacity of 112.2 ml CH_4 per minute. For compost, the oxidation capacity is 169.8 ml of CH_4 per minute. From this study we concluded that compost has greater potential than black soil as landfill cover material due to the better CH_4 oxidation capacity.

(**Key words**: CH_4 oxidation, compost, black soil, Biocover)

INTRODUCTION

Wastes are discards that are no longer useful or required after the completion of a certain process. Currently, on average, Malaysians produces about 1.3kg/ capita of MSW. However, in urban areas such as Kuala Lumpur, Petaling Jaya and Georgetown, the rate can be up to 2.0kg/ capita [1]. Due to the high per capita generation, daily generation of MSW in Malaysia totaled to more than 31,000 tonnes where 95% of it will be sent to landfill. The practice is absolutely unfavorable in most of the developed nation as it will result with total loss of resources to landfilling process. Landfilling is the most favored practice in Malaysia since recycling or material recovery only covers 5% of the total waste generated [2].

Most landfills in Malaysia are small scale operations with a variety of technology being used. However, most of the sites are poorly managed. As of January 2011, there are a total of 296 landfills in Malaysia, with 166 being operational and 130 more being closed. However, of the total of 166 active landfills, there are only 8 of which are sanitary landfills [3].

Landfills containing organic wastes produce landfill gas (LFG) consisting primarily of CH_4 and carbon dioxide. Landfills are significant sources of atmospheric CH_4 that contribute to climate change [4]. CH_4 emissions from landfill are ranked third among the anthropogenic CH_4 sources and ranged between 19-40 Tg/yr. CH_4 is recognized as a potent greenhouse gas with the global warming potential of approximately 25 times than that of carbon dioxide [5]. The annual global CH_4 emissions from landfills are estimated to be in the range of 500-800 MT CO2-eq, representing the highest source of greenhouse gases within the waste sector [4].

Biocover is a layer of biologically engineered soil or compost, able to oxidize CH_4 generated by landfill. In

Malaysia, the typical landfill gas components are CH_4 (55-60%) and carbon dioxide (40-45%) with the rest being carbon monoxide, hydrogen sulfide and ammonia. Many landfills in Malaysia and other developing countries are not equipped with LFG extraction facilities and have been covered with low permeable clay soils to reduce infiltration of water to the waste layers. Besides, the quantity of produced gas is often too low for gas utilization systems to be economically feasible and therefore, Biocover represents a cost-efficient solution. Usage of biologically engineered cover materials might be needed at older landfills with a relatively low gas production. The selection of suitable materials represents one of the key issues in constructing biotic CH_4 oxidation systems. In general, well textured, porous substrates should be employed since they provide sufficient porosity for gas exchange, facilitating the penetration of oxygen from the atmosphere and CH_4 supply from waste, with both being crucial to microbial CH_4 oxidation processes. Besides, the microbial oxidation process is also influenced by other factors such as temperature, moisture content and the prevailing physical and chemical soil conditions [6]. Numerous composts and soils have been investigated by our centre in various studies aimed at assessing CH_4 oxidation. The above-mentioned materials were tested under similar laboratory conditions in Wheaton bottle set-ups. The data set has been compiled focusing on routine chemical, physical and maturation parameters. Finally, it has been established that compost from grass clippings and cow manure provides the most optimum CH_4 oxidation under laboratory conditions

The aim of this study is to identify the materials suitable for Biocover and also the CH_4 oxidation capacity of compost and black soil under field conditions.

MATERIALS AND METHOD

Experimental materials

Compost was obtained by composting a mixture of 75% grass clippings and 25% cow manure. The materials were uniformly mixed to ensure even distribution of microbes for optimum composting to occur. Heap method was employed in the process and composting was carried out under a well aerated shade. Water was added to the compost mixture to maintain the moisture level at 60% for proper decomposition of the raw materials. Proper aeration and aerobic condition was maintained by manual turning of composting mixture with daily mixing for the first 8 days and then mixing on alternate days. Temperature of the composting mixture was measured daily using the electronic thermometer (model Oregon scientific SA880SSX). The moisture content was determined gravimetrically by oven drying compost at 104^0C for 24 hours and expressed as the mass ratio of water to drying compost, following the ASTM (2004) procedure. The pH of the compost was measured using the pH meter model HANNA HI 8424. The organic matters were obtained according to ASTM 830-97 standard method. The total Carbon was obtained according to ASTM 777-87 (96) method and total Nitrogen was obtained according to the ASTM E778-87 respectively. Black soil was obtained from a local nursery.

Site characterization

Field study was carried out at Jeram Sanitary Landfill. The Jeram Sanitary Landfill is an active landfill located at Lot No. 1595, 2598, 2959 in Jeram Town, Kuala Selangor district with an approximate area of 160 acres. Former land-use was agriculture. The landfill is currently awarded a 25 year privatization-cum-concession for the construction, operation and maintenance of the area. A total of approximately 2100 tonnes of municipal solid waste is disposed of at the landfill daily. The dominating waste types are domestic waste, bulky waste and garden waste. The landfill caters for seven major municipalities in Klang Valley namely Kuala Selangor, Subang Jaya, Klang, Petaling Jaya, Shah Alam, Ampang Jaya and Selayang. JSL started operation on 1st January 2007 with an expected lifespan of 16 years dependant on the amount of wastes received.

Column reactor experiments

Hot spots for landfill gas emissions were identified onsite with portable gas analyzer Binder CombiMass GA-M Type GFM 415-1 at different sections of the landfill. Surface LFG emissions readings and LFG emissions from sampling ports present at landfill at various locations were evaluated quantitatively and qualitatively. These field measurements were generally planned so that measurements were carried out under stable weather conditions, where the measured emissions are believed to be representative for the whole landfill emission rate at the particular time. The gas sampling port GV1 at Jeram Landfill was selected as experimental site.

One-meter high columns were specially fabricated using 10mm thick PVC pipes with an internal diameter of 0.14m **(Figure 1)**. Sampling ports were embedded in the columns at an interval of 0.1m to enable gas sampling at different heights. Biocover materials were placed in the columns with the top of the column being sealed with 5mm thick Plexiglas.

Figure 1: BioCover column

LFG were introduced into the cover material through the bottom inlet valves. Gas composition and pressure were monitored at selected profiles. At the bottom of the column, controlled flow of LFG was introduced using Dwyer Rate-Master Flow meter through an inlet. Exhaust gas from each sampling port was analyzed using the portable gas analyzer Binder CombiMass GA-M Type GFM 415-1 for CH_4, carbon dioxide and oxygen. Column reactor experiments were conducted in triplicates using compost and black soil with flow rates of 100 ml/min, 200 ml/min and 300 ml/min. Readings were taken at the temperature of 35^0C during the day as it is acknowledged that it is the optimum temperature for CH_4 oxidation to occur.

RESULTS AND DISCUSSION

Landfill gas (LFG) is produced by microbial anaerobic degradation of the organic fraction in waste disposed in landfills. The biodegradable organic materials in waste mostly include paper, animal and vegetable matter, and garden waste. The main components in LFG are CH_4 (55-60%), and carbon dioxide (40-45%). **Table 1** shows the average percentage of surface CH_4 emissions of JSL for the past one year.

Table 1. Average percentage of CH_4 emissions at Jeram Sanitary Landfill

Month	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
CH_4 (%)	48.43	59.83	56.42	39.44	48.78	49.52	53.70	45.65	57.36	53.94	53.73	55.48

Figures 2a, b, and **c** shows the reduction of CH_4 in exhaust gas with the increased flow rate of LFG input respectively for black soil. The height needed to fully oxidize the CH_4 from LFG increases with the respective increase in the flow rate. However for the flow rate of 300ml/min, 100 cm of black soil is unable to fully oxidize the input of 300 ml per minute of LFG. The maximum oxidation capacity of 100 cm of black soil is 112.2ml of CH_4 per minute. **Figures 3a, b** and **c** show the reduction of CH_4 in exhaust gas with the increased flow rate of LFG input respectively for compost. The height of 100 cm for compost can fully oxidize a maximum of 300 ml per minute of LFG. Therefore the maximum oxidation capacity of compost at 100 cm is 169.8 ml of CH_4 per minute.

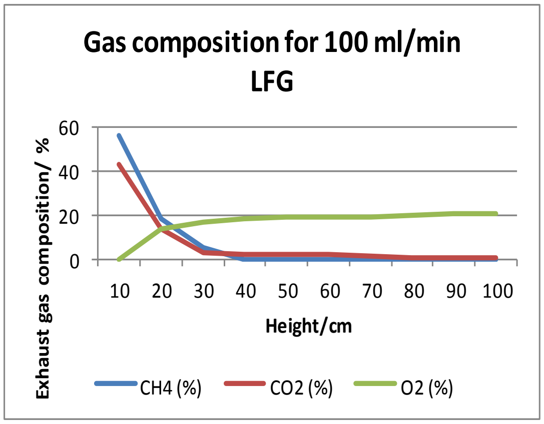

Figure 2a Black soil with 100 ml/min of LFG

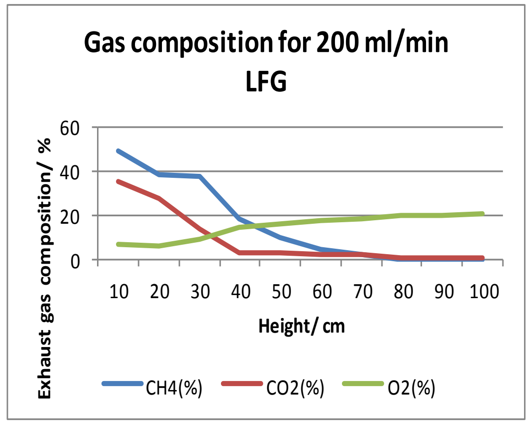

Figure 3a Compost with 100 ml/min of LFG

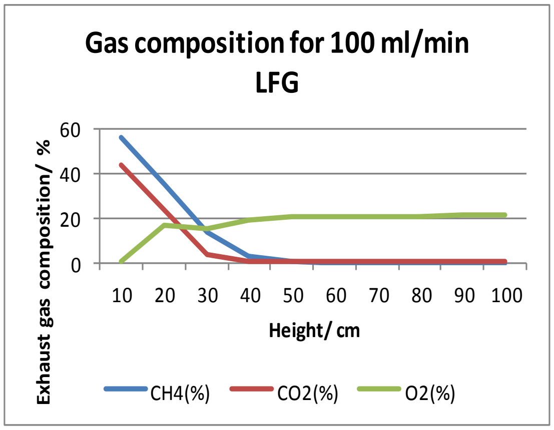

Figure 2b Black soil with 200 ml/min of LFG

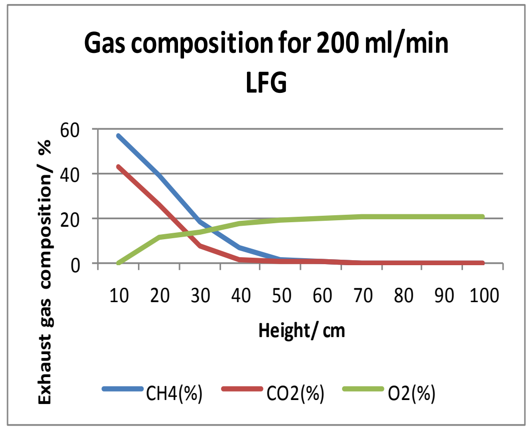

Figure 3b Compost with 200 ml/min of LFG

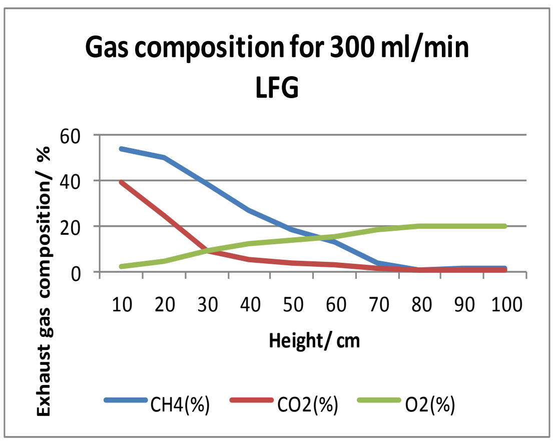

Figure 2c Black soil with 300 ml/min of LFG

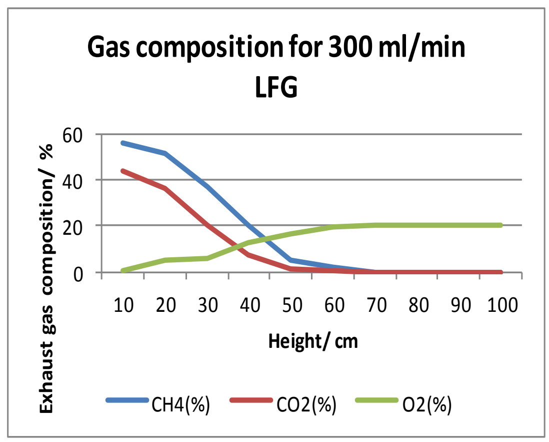

Figure 3c Compost with 300 ml/min of LFG

Table 2 shows the summary for CH_4 oxidation capacity of compost to be at the height of 90cm for the maximum flow rate of 300 ml/min. The height for full CH_4 oxidation for black soil is lower than compost for 100 ml/min flow of LFG 33% better than compost. However, at 200 ml/min, compost out performs black soil by 22%, and at 300 ml/min the maximum height (100cm) of black soil is insufficient for oxidation. Overall, column experiments using compost exhibited better CH_4 oxidation compared to black soil.

Table 2. BioCover oxidation capacity

Flow rate (ml/min)	**Height of full oxidation (cm)**	
	Compost	**Black soil**
100	60	40
200	70	90
300	90	>100

The above results show that CH_4 oxidation capacity of black soil is lower than that of compost. The reason behind the difference in oxidation capacity can be explained from the physiochemical properties of both cover materials. This could be due to the acidic condition of the soil which inhibits the methanotrophic activity in black soil. According to Pawloska [7], it is also possible that the drop in CH_4 concentration could be the result from the activity of yeasts that easily adapts to an acidified medium.

Table 3. Physiochemical properties of compost and black soil used for CH_4 oxidation

Test parameter	**Compost**	**Black soil**
Moisture content	63.17 ± 0.14 %v/v	43.12 ± 0.14 %v/v
pH	6.33 ± 0.12	6.02 ± 0.12
Organic matter	63.6 %	40.0 %
Total carbon (%)	20.3 %	16.2 %
Total nitrogen	1.20 %	1.10 %
Carbon: Nitrogen ratio	17.0	14.7

Table 3 shows the physiochemical properties of the Biocover materials namely compost and black soil. The compost moisture content is significantly higher than that of black soil. The ability of Biocover material to retain water is important to sustain microbial population responsible for CH_4 oxidation. According to Pawloska [7], CH_4 oxidation becomes limited if there is lack of water due to the physiological stress to methanotrophs present in cover material. Hilger and Humer [8] indicated that compost offers good water holding capacity, thus optimizing CH_4 oxidation.

As indicated in **Table 3**, the organic matter present in cover materials produces a significant impact on oxidation performances [8]. Literature reports provide extensive proof of the effects of organic matter content on physical parameters in soil [9]. The nutrient status in a substrate is substantially affected by the organic matter content. Compost, with higher organic matter and carbon & nitrogen content performs better than black soil in CH_4 oxidation. Methanotrophic bacteria have a relatively high nitrogen demand [10].

Data from field studies have also shown the relative decrease in ammonia with increase in time and column height. Therefore for field applications, it is important for cover materials to provide sufficient nitrogen supply to support CH_4 oxidation. However, landfills with a high ratio of CH_4 to nitrogen may cause limitation of inorganic nitrogen for the bacterial colony present in the cover materials [11]. Field and laboratory studies also show CH_4 oxidation rate in landfill cover soils change with ambient conditions [12], [13], and [14]. However, the sensitivity of CH_4 oxidation to environmental factors in landfill cover soils, especially in nitrogen stress, including ammonia volatilization and nitrification is still not well known.

Anaerobic oxidation of CH_4 occurs in marine, sediment and submerged soils [15], [16], [17], but most CH_4 is consumed in landfill covers under aerobic condition. The CH_4 oxidation rate was low atthe base of the columns. This was probably due to the existence of oxygen in the soil porosity, where aerobic CH_4 oxidation occurred. As oxygen concentration increased, cover CH_4 oxidation reduction presented an increasing trend.

Another important parameter provided by organic matter in a material capable of enhancing CH_4 oxidation is the internal specific surface area which is the surface area to volume or mass ratio. In biofilter operation, specific surface area is regarded as the determining factor underlying mass exchange and biological reaction [18], [19]. Although it is an acknowledged fact that specific surface area increases with the higher organic matter content in a substrate, specific surface area parameter has been rather neglected to date [20].

CONCLUSION

The results from this study have shown that compost has a better CH_4 oxidation capacity of than black soil under field conditions. At 100 cm of cover height and flow rate of 300 ml per minute, black soil has an oxidation capacity of 112.2 ml CH_4 per minute. For compost, the oxidation capacity is 169.8 ml CH_4 per minute. However, further studies on other parameters in this experiment are still ongoing.

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