CHAPTER 1

INTRODUCTION

1.1 Waste Generation

Waste refers to any material or product that has no value in the perception of the generator or consumer. The generation of waste increased tremendously due to the increase in population and in Malaysia it increased at 3% annually (Agamuthu, 2001). As Malaysia is moving towards becoming a developed country by the year 2020, advancement in the country's development also caused an increase in waste generation. In Malaysia, waste generation is mostly Municipal Solid Waste (MSW) and 95% of MSW generated waste was sent to the 260 landfill sites throughout the country while only 3% to 5% of the MSW are recycled (Agamuthu *et al*., 2009). According to Agamuthu *et al* (2009), the per capita generation in Malaysia is 1.3 kg per day. The daily generation of MSW was 18,000 tonne in 2004 compared to 30000 tonne in 2011(Agamuthu *et al.*, 2004; Agamuthu *et al*., 2011). There is an increase of 66.6% in the daily generation of MSW within 7 years. This has caused an alarming situation for the need of proper waste management to minimize the impacts to the environment and all the inhabitants on the earth. Lack of awareness, facilities and technologies are some of the major factors for improper waste management (Chowdhury, 2009). According to Fauziah *et al* (2009), effective waste management also requires necessary laws and regulations. Solid Waste and Public Cleansing

Management Act 2007, was implemented in September 2011 with a two years grace period before strict enforcement would take place (Fauziah and Agamuthu, 2012).

1.2 Landfill

Final disposal is an important component of waste management hierarchy because there are no technologies available to avoid the entire unwanted residue from the waste sector and no endowment is available for zero waste (Fauziah and Agamuthu, 2012). Landfill is the option of choice in Malaysia for waste management system, compared to other technologies such as incineration or composting. Landfilling is the oldest and most popular method for waste disposal. There are total of 166 operating MSW disposal sites in Malaysia in 2011 including 11 operating Sanitary landfills (Fauziah and Agamuthu, 2012). Landfill or dumps are mostly non-sanitary in Malaysia which pose serious threat to the environment. Disposal of waste by landfilling has become more difficult as the existing landfills are filled up at a very fast rate and constructing new landfill has also become a challenge because of lack of space and increasing land price. According to Irigaray *et al* (2007), improper waste disposal not only pollutes the environment but also leads to waste borne diseases. The major outputs of waste disposal in landfill are landfill gas and leachate.

1.3 Landfill Gas

Landfill gas (LFG) is output of the microbial degradation of solid wastes. The rate of landfill gas production depends on the size and composition of the solid waste, age of the solid waste and age of the landfills, moisture content, temperature conditions in the landfill, quantity and quality of nutrients, organic content of refuse, pH and alkalinity of liquids in the landfill and presence of toxic or hazardous materials (Agamuthu, 2001). There are four main phases involved in the production of landfill gas after the waste has been deposited into landfill. Phase I is the Aerobic decomposition, Phase II is Acidogenesis, Phase III is Acetogenesis and finally Phase IV is Methanogenesis. Figure 1.1 shows LFG production phase and time variations of the landfill. The landfill gas consists of CH_4 (50-60% by volume), CO_2 (35%), volatile organic compounds (VOC) which is less than 1% and small amounts of N_2, 0_2, $H_2$and trace amounts of inorganic compound (Kettunen *et al.*, 2003). The constant production of landfill gas increases the pressure within the landfill and causes the gas to be released into the atmosphere. Other than the environmental concerns of methane emission and unpleasant odors associated with landfill gas such as H_2S, uncontrolled landfill gas can present a serious explosion hazard. According to Scheutz *et al.*, (2009), the landfill gas production can happen for several decades depending on the organic materials in the waste. Waste disposal is an important source of anthropogenic greenhouse gas emission (EPA, 2002). CH_4 emission in developing countries such as Malaysia is estimated to increase up to 60% within the next two decades with the increase in human populations (Meadows *et al.*, 1997). Improper gas collection system in landfills resulted in passive release of landfill gas to the atmosphere and causes large impacts to environments. Plate 1.1 depicts the passive release of landfill gas in Malaysia's landfill.

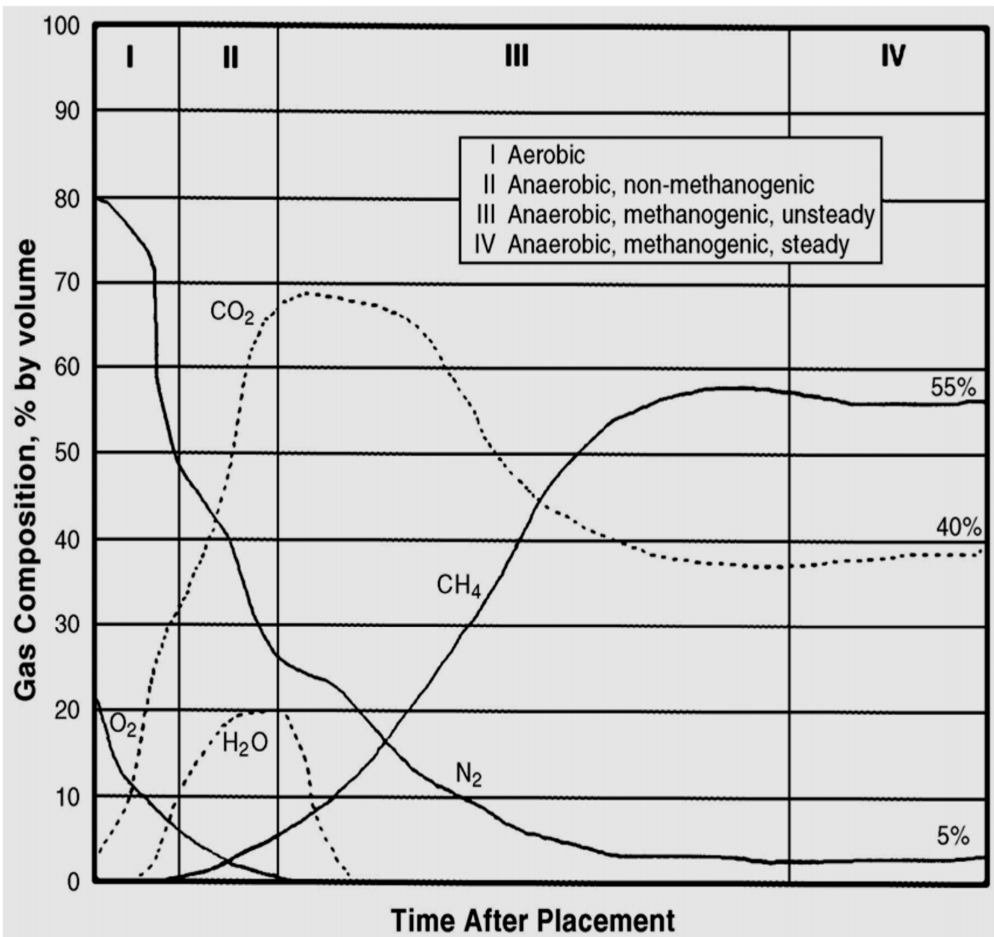

Figure 1.1: LFG production phases and times variation of landfill (USEPA, 2005)

Plate 1.1: Passive release of landfill gas to the atmosphere (Fauziah, 2010).

1.4 Global Warming

Global warming is the average increase in the earth's surface temperature which causes changes in the global climate patterns (USEPA, 2011). According to the Intergovernmental Panel on Climate Change (IPCC) (2007), the sea level has risen by 17 cm since the 19th century. Global warming poses a very serious threat to urban infrastructure, quality of life, and entire urban systems (World Bank, 2010). Landfills are significant sources of atmospheric greenhouse gas which has contributed to global warming (Bogner *et al*., 2007). Both CH_4 and CO_2 are the landfill gases which been recognized as a primary contributors to the global warming. CH_4 is a particularly potent GHG, and is currently considered to have a global warming potential (GWP) 25 times that of CO_2 in a time horizon of 100 years (IPCC, 2007). CH_4 is found to have a very strong absorption band in the infrared region of the solar spectrum (Pawloska, 2008). CH_4 also poses a serious threat to the environment compared to other gases as it contributes largely to global warming. The annual global CH_4 emission from landfills is estimated to be in the range of 500- 800 MT $C0_2$-Eq and represents the highest source of GHG within the waste sector (Bogner *et al.*, 2007). Approximately 18% of the global CH_4 emission is from landfill and waste water which contributes 90% of the total emission from the waste sector. Malaysia's landfill produced about 2.7 $X10^6$L of CH_4 daily (Agamuthu, 2010). Most of the landfills or dumps in Malaysia are non sanitary and the CH_4 are passively released to the atmosphere. The reduction of CH_4 from landfill is essential in order to reduce and mitigate greenhouse gas emissions.

1.5 Methane Oxidation

There are several options for LFG mitigation and one of them is by LFG recovery system but the cost is very high and there are other requirements to be fulfilled. On the other hand, it is suitable only for large scale landfills. Landfill gas recovery method has been proven to be one of the best method for CH_4 mitigation but system installation cost is very high (ATSDR, 2001) and besides that, LFG recovery system can only achieve efficiency of 50% to 60% (Borjesson *et al*., 2009). CH_4 is the potent greenhouse gas that requires more concern and it can be converted to CO_2 which is less harmful GHG by oxidation process. Methane oxidation is the process of converting CH_4 into CO_2, water and biomass by the microbial activity and it plays a vital role in the atmospheric CH_4 emission from landfills (Kightley *et al.*, 1995).

Methanotrophic properties are also potential for reduction or mitigation of CH_4 in landfill (Pawloska, 2008). The CH_4 oxidation process depends on several factors, for example, moisture content, temperature, CH_4 concentration, oxygen availability and nutrient concentrations (Kettunen *et al*., 2006). Previous studies reported that CH_4 oxidation rate is higher when the season is warmer (Borjesson *et al*., 2001). Suitable landfill cover is important for methanotrophic bacteria to carry out oxidation process.

1.6 Biocover As Landfill Cover

Biocover is a filter material that supports growth of methanotrophs, where it is placed above a gas distribution layer (Scheutz *et al*., 2009, Hilger and Humer, 2003). In Malaysia's landfill, clay is used as landfill cover to reduce rain water infiltration and thus minimization of landfill leachate. Design of the final cover is an important aspect as it will determine the performance of landfill. Main purpose of dedicated landfill cover is to reduce water infiltration into landfills. Clay as landfill cover has been reported not suitable because serious explosions can occur due to the pressure build up (Kjeldsen and Fisher, 1995). Proper cover materials are needed in order to mitigate CH_4 emission. Emission of CH_4 can be oxidized by addition of small amount of organic wastes in biologically active biocovers (Hilger and Humer, 2003; Barlaz *et al*., 2004). Passively aerated low maintenance biocovers are potential for CH_4 mitigation. Compost has been proven to be very efficient in mitigating CH_4 emissions (Humer and Lechner, 1999; Hilger and Humer, 2003; Barlaz *et al*., 2004; Abichou *et al*., 2006a; Stern *et al*., 2006). Compost is an organic rich material which has the ability to retain water, rich with methanotrophic bacteria and 100% oxidation was reported for field conditions (Stern *et al*., 2006). According to Humer and Lechner (2001), compost as cover material has been found to oxidize the CH_4 emission of almost 100% under the test site conditions. Biocover is one of the inexpensive methods to reduce CH_4 emission. Besides that, compost as biocover material is considered to be environmentally harmless and able to enhance the soil bacterial activity (Garcia *et al*., 1994).

1.7 Methanotrophic Bacteria In CH_4 Oxidation

Methanotrophs are a group of microorganisms that utilize CH_4 as its sole carbon and energy source in the presence of O_2. The presence of methanotrophic microorganisms from different natural systems has been known since long time by scientific community (Whittenbury, 1970). It has been estimated that anywhere from 10% to 100 % of the CH_4 generated in landfills is oxidized by this bacteria (Borjesson *et al*., 2001). It also has been identified to be the important regulators of atmospheric methane fluxes in nature (Denier and Neu, 1996). Methanotrophs oxidizes CH_4 to methanol using the enzyme methane monooxygenase (MMO). Methanotrophs which has the potential to oxidize CH_4 was first isolated from soil sample close to a leakage of the natural gas by Songen in 1906 (Mancineeli *et al*., 1981). It is also divided into two categories which are type I and type II. Type I bacteria is associated with low CH_4 concentration and Type II bacteria is associated with high CH_4 concentration (Hanson and Hanson, 1996). Another unique property of type II bacteria compared to type I bacteria is their ability to fix nitrogen. Methanotrophic bacteria grow well in mesophilic conditions and they are mostly gram negative bacteria. Environmental factors showed a direct effect on the methane oxidation by methanotrophs. According to previous reports, the methanotrophic bacteria activity on methane activity are influenced by several factors including climate variables such as moisture and temperature (Bogner *et al*., 1995), CH_4 concentrations, type of soil and pH (Hilger *et al*., 2000) .

1.8 Problem Statement

The Malaysian MSW generation is increasing at 3% annually with the increase in human population and development. Malaysian MSW generation is about 30,000 tonnes daily. Even though there are several disposal methods available for waste disposal, landfill is the most employed method in Malaysia, where 95% of MSW generated is landfilled. Current waste management practice in Malaysia is below the standards seen in developed countries. Almost all landfills in Malaysia except for 12 sanitary landfills passively releases the gas produced from decomposition of waste to the atmosphere and contributes directly to greenhouse gas emission. Greenhouse gas contributed to the global warming and poses a serious threat to the environment. CH_4 has been identified as one of the most important greenhouse gas. Mitigation of CH_4 from landfill is necessary because waste sector is reported to contribute to 18% of the total greenhouse gas emission. Biocover technology will be applied in this study for the reduction of CH_4 emission in landfill by making use of methanotrophic bacteria to convert CH_4 to CO_2 under tropical conditions.

1.9 RESEARCH OBJECTIVES:

1. To identify and analyze physiochemical properties of biocover material.

2. To isolate and identify the methanotropic bacteria and assess the methane oxidation potential of these methanotropic bacteria.

3. To assess the methane oxidation efficiency of the biocover material, using Wheaton bottle experiment

4. To evaluate the efficiency of the methane oxidation with the addition of methanotrophic bacteria as individual culture and mixed culture to the biocover material using Wheaton bottle experiment and Column experiments, at various parameters.