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POWER GENERATION FROM LANDFILL GAS

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Abstract. Landfilling is one of the most commonly adopted technologies for Municipal Solid Waste (MSW) disposal as an alternative to waste burning and composting. The sanitary landfill method continues to be widely used in different countries for the final disposal of solid waste material due to its economic advantages. Landfill gas (LFG) mostly results from the anaerobic decomposition of biodegradable fraction namely kitchen and yard waste in the MSW that is disposed of in the landfills. Landfill gas is continuously generated due to the anaerobic degradation of the organic fraction of solid waste. Therefore, in a landfill in which an extracting system is not installed, there will be an overpressure that will force the biogas to be released into the atmosphere. Landfill gas is a mixture of several gases with its main constituents being methane and carbon dioxide. Landfill gas can be collected by either passive gas collection system or active gas collection system, both of which consist of gas collection wells that provide a preferential migration route for the landfill gas. The Mare Chicose landfill site has an active gas collection system that uses a blower to draw out the gas from both the horizontal and vertical gas wells. It was assumed that the landfill gas consists of methane and carbon dioxide only. The average composition of methane is 49% by volume and therefore the composition of carbon dioxide was assumed to be 51% by volume. This study was therefore initiated to assess the amount of landfill gas generated and determine the amount of power that could be generated.

Data was collected from relevant authorities to find the amount of waste being deposited in the landfill. A model was developed for predicting the amount of landfill gas generated from the landfill which could be used for power generation. Data was also collected from the existing landfill on the amount of waste disposed, on the composition of landfill gas and the amount of landfill gas generated so far. The model was validated using the collected data. The model was then used to predict the amount of power that could be generated from the landfill gas.

Based on the flow rate of the landfill gas, it was found that the amount of power generated will vary over time. It will initially increase until it reached a peak. In the case of the Mare Chicose landfill the peak will be reached in 2012 and after this it will decreased. It was found that the amount of power produced in 2010 would be 50.50 GWh

Keywords: Solid waste, landfilling, landfill gas, power

1. Introduction

Landfilling is one of the most commonly adopted technologies for Municipal Solid Waste (MSW) disposal as an alternative to waste burning and composting. The sanitary landfill method continues to be widely used in different countries for the final disposal of solid waste material due to its economic advantages.

The Mare Chicose landfill is the only landfill in Mauritrius situated in the village of Mare Chicose in Grand-Port district. The site is approximately square in shape with an area of about 20 hectares. The landfill is owned by the Government and is managed by Sotravic Limitée for a 10 year contract as from November 2006; previously, it was managed by Société de Traitement et d'Assainissement des Mascareignes Limitée (STAM). It has begun its operation in November 1997 and has since then been accepting MSW from all the transfer stations and from the southern region of Mauritius. It is a wet landfill of a class II type; therefore it

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receives MSW consisting of a high percentage of organic matter which is buried in excavated cells. The landfill consists of 6 cells and 5 out of these 6 cells have already been filled.

Waste disposal in landfills can generate environmental problems such as water pollution and greenhouse gas emissions [1]. Moreover, the gases generated in landfill through the degradation of organic waste can be used as a source of energy. This study was therefore initiated to assess the potential of using landfill gas for power generation.

2. Methane Generation Potential

The methane generation potential per ton of waste, L_o, depends on the fraction of organic matter present in the refuse. It could be estimated using the stoichiometric and the biodegradability methods or the IPCC 2006 guidelines. The stoichiometric and the biodegradability methods are perfect biological systems whereby all the degradable organic materials are assumed to be converted to carbon dioxide and methane. However, in practice not all the organic carbon present in the waste biodegrade to produce landfill gas. The resistant materials (such as lignin) present in the waste and plastics materials retained in plastic bags, for instance, are less prone to biodegradation. Therefore the IPCC method, which gives a much realistic estimate, was used to estimate the methane generation potential. The following data was used to determined methane generation potential:

- Degradable organic carbon (DOC), base of the composition of the Mauritian MSW, was found to be 0.1706 ton carbon/ton waste.
- Methane Correction Factor for Mare Chicose Landfill was assumed to be 1 as it satisfies the criteria of a well managed landfill.
- Fraction of DOC Dissimilated, DOC_f, was found to be 0.77.
- The average Fraction of methane in landfill gas in the Mare Chicose landfill was found to be 49.7%.

Based on the estimation of different parameters needed, methane generation potential was found to be 0.0858 ton methane/ ton MSW which is equivalent to 119.8 m^3 methane/ton MSW. Therefore, the amount of LFG produced would be 241 m^3 LFG/ton MSW.

According to the IPCC guidelines (2006) [2], the value of L_o ranges from 100 to over 200 m^3 methane/ton waste. This shows that the estimated value of L_o is within acceptable range. Several researchers have also studied the methane generation potential of MSW. Faour [3] estimated that the methane gas generation potential was 115 m^3/ton of waste for a wet landfill. Krumpelbeck [4] collected data from several landfills and concluded the methane generation potential to be in the range of 100–170 m^3/ton.

3. First-Order Decay Rate Constant

It is very important to have a good estimation of rate constant, k value, as the estimation of methane production from the landfill is extremely sensitive to it. The k value can either be taken from IPCC 2006 Guidelines as default value or estimated by calculation. The k value in this study was determined using Landfill Gas Emissions Model Version 2.0 which is also known as the the LandGEM software. The LandGEM used site specific parameters to determine the rate constant for the Mare Chicose landfill. The rate constant was found to be 0.057 $year^{-1}$.

4. Landfill Gas produced

A projection of the LFG generation up to 2050 was done for the Mare Chicose landfill as well. Figure 1 shows the landfill gas production profile up to the year 2050. The graph showed that the amount of landfill gas would keep on increasing until it reached a maximum in 2012 where 22.9 Mm^3 methane would be produced and 46.7 Mm^3 LFG gas would be generated. After 2012, no more waste would be placed in the present available space, however, the landfill gas would continue to produce but at a lower rate.

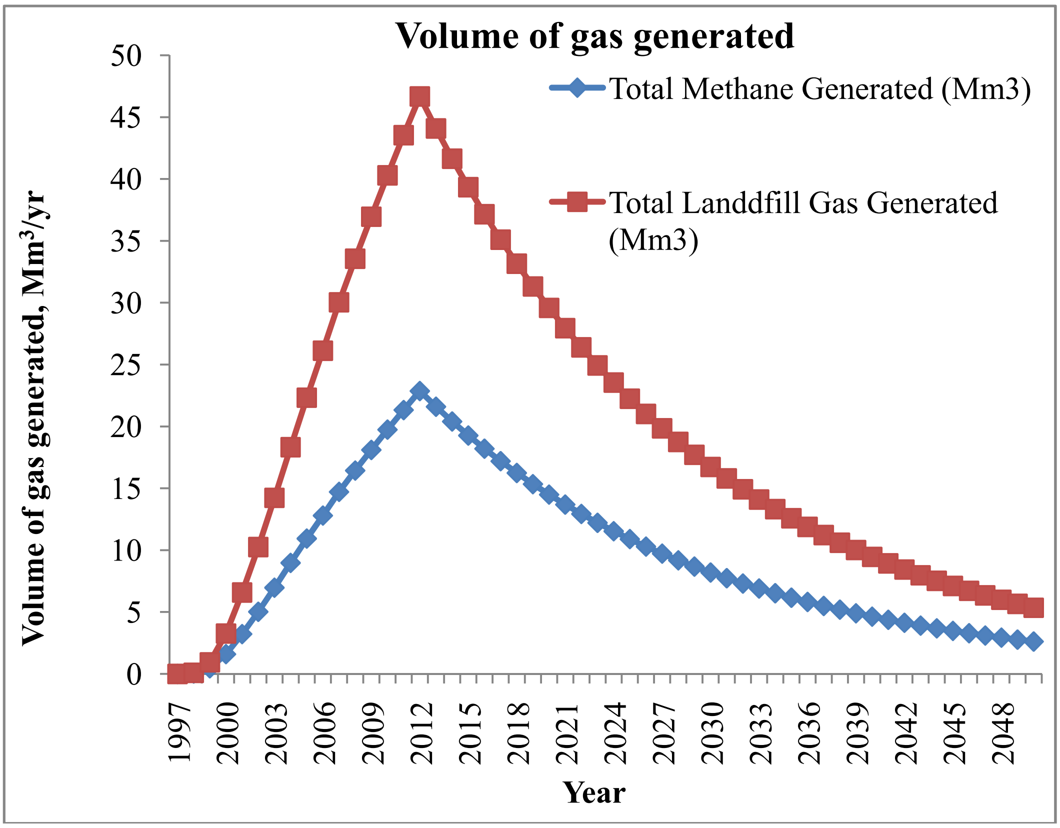

Figure 1: Landfill gas production profile

5. Power Generation

The use of LFG for generating electricity is a promising approach both in terms of conserving energy and also for reducing air pollution. Energy recovery from waste represents an important way to reduce the amount of electric energy to be produced using fossil fuels, that is, non-renewable sources of energy. There are many incentives in using LFG in waste to energy conversion systems. In addition to conserve valuable alternative energy resources, direct LFG utilization results in reduced greenhouse gas emissions.

The amount of thermal energy generated from the landfill gas could be found using equation below.

Thermal energy, E_{th} (MW) = $\dot{m}_{CH_4} \times LHV_{CH_4} \times \Re$

Where,

$\dot{m}_{CH_4}$ - Flow rate of CH_4 (m^3/h)

LHV_{CH_4} - Lower heating value of CH4 (MJ/m^3)

$\Re$ - Recovery rate

The amount of power could be computed using the electrical conversion efficiency using the equation below.

Electrical energy, E_{el} (kWh) = $\dot{m}_{CH_4} \times LHV_{CH_4} \times \Re \times \eta_{el}$

Where

η_{el} - Electrical efficiency

There are several facilities using landfill gas for the production of power that are in operation worldwide utilizing gas engines, gas turbines and steam turbines [5]. The gas engine had an advantage over the other facilities in the sense that it produced less waste heat, therefore, increasing its efficiency.

The amount of landfill gas forecasted was used to estimate the amount of power that could be generated from the landfill gas. A gas engine was used to burn the landfill gas and estimate the power produced on site.

A recovery rate of 75% of LFG and the efficiency of gas engine of 33% was assumed. The different parameters used to input in the models are shown in Table 7.9.

Table 1: Parameters used as input in the model for the year 2010

Parameters		Unit
Input		
Mass flow rate of methane	19.7	Mm^3/yr
LHV of methane	37.5	MJ/kg
Density of methane	0.000717	$tons/m^3$
Recovery rate of biogas	75	%
Efficiency of gas engine	33	%
Output		
Power	50.5	GWh

It can be seen from the Figure 2 that the profile of the graph for power generation annually is the same as the one for landfill gas production except that the power generation was computed as from 2010. The amount of power produced in 2010 would be 50.50 GWh and it could be seen from the graph that it would reach a peak power in 2012 with 58.49 GWh. It would be worth pointing out that both the landfill gas production and power produced reached a peak value in 2012.

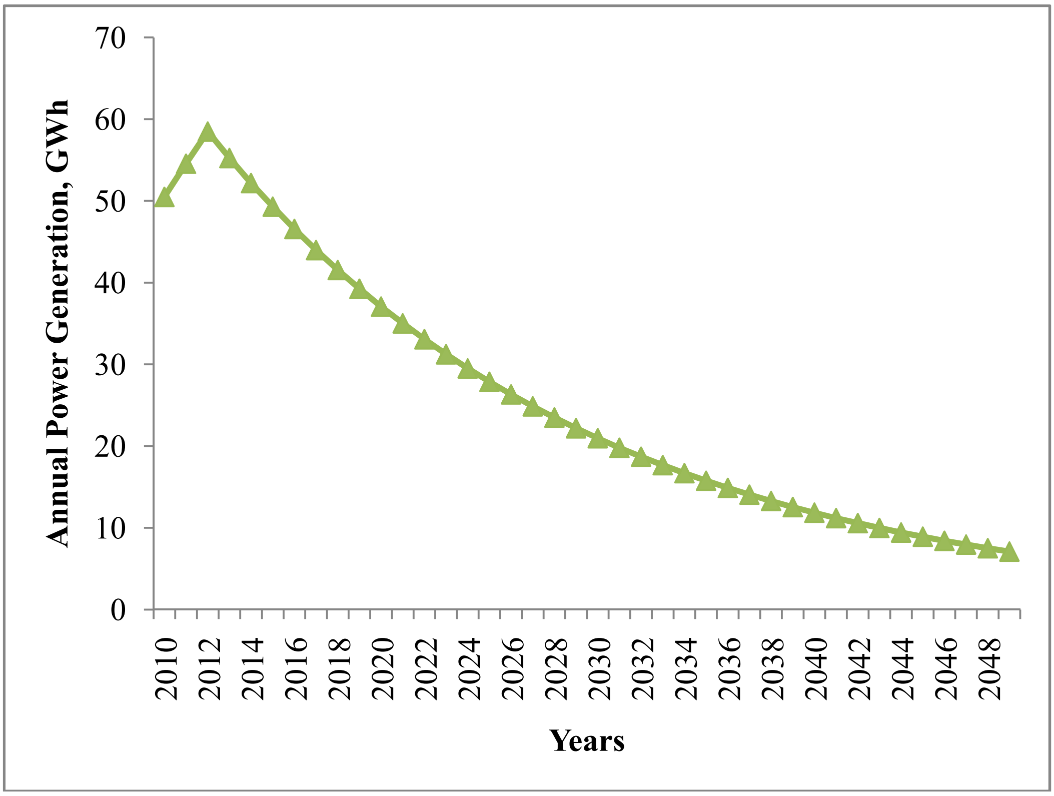

Figure 2: Power Generation Annual

6. Conclusion

The use of LFG for generating electricity is a promising approach both in terms of conserving energy and also for reducing air pollution. It was found that the amount of power produced in 2010 was 50.50 GWh and it could be seen from the graph that it would reach a peak power in 2012 with 58.49 GWh. It would be worth pointing out that both the landfill gas production and power produced reached a peak value in 2012. It can therefore be concluded that LFG is a good source for power generation and it can be used to displaced fossil fuel.

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