Estimation and Utilization of Landfill Gas from Egyptian municipal wastes, a case study

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Abstract

Purpose

As the first Author had the chance to invest in landfill gas plant (EL Hammam plant) that flare approximately 1000 m³/hr. to generate electricity. Two critical question must be answered in order to proceed with the feasibility study. The three questions are:

1- How many years this landfill gas emission will last?
2- How much energy can be generated from one million ton if landfilled?
3- How much CO₂ in tons will be saved during the project life time?

Methods:

Experimental method is used to determine BMP (Biochemical methane potential) ton CH₄/ton waste. With results we can know the potential of generating electricity from landfill sites.

Results

The results showed that for every ton of municipal waste, 140 m³ of landfill gas can be produced.

Conclusion

Using landfill gas emissions for electricity production have several benefits, which can be summarized it as follow:

- Creating revenues from “waste”.
- Significant emission and risk reduction.
- Landfill management improvement.
- Renewable energy production.
- Reduction of greenhouse gas emission (methane).
- Reduction of indirect greenhouse emission (fossil fuels).
- Improvement of local air quality.
- Improved living conditions.
- Stimulation of local economy.
- Creating new jobs and business opportunities.
- Replacement of fossil fuel by renewable energy.

Keywords— Landfill biogas, Municipal solid waste, Methane emission, energy from landfill gases, renewable energy sources.
1.1 Introduction

Municipal waste should be considered as a valuable biomass resources that could contribute to Egyptian energy portfolio. As a rule of thumb, one million ton of municipal waste is enough to power one-megawatt engine for a period ranging from 10 to 15 years [GE waste to energy seminar in Cairo, Egypt], however, this rule had been applied for European and American landfill. This study's objective is to see how much we can extract from Egyptian landfill. The study will approach as the follow steps:

- Presenting the actual data from El Hammam landfill our case study.
- Experiment to determine (BMP), how much landfill emission (m3/ton) will be produced from 1 ton of municipal waste (it worth noting that this study is the first one to determine the value of 1-ton municipal waste emission in Egypt).

1.2 Sources of biomass in Egypt

There are various sources for biomass in Egypt like municipal wastes, wastewater, industrial waste, animal droppings (cattle, chicken …) and crop residues. It is hard to have an accurate estimation of total biomass in Egypt but a conservative estimation showed that the total biomass estimation is around 14 million-ton equivalent of petrol. The available that can be used in the energy sector is around 6.6 million-ton equivalent. Table 1 summarizes the available quantity from each source. [1]

Table 1, Available biogas sources. Source: The Egyptian cabinet information and decision support center

<table>
<thead>
<tr>
<th>Waste</th>
<th>Quantity</th>
<th>Available to generate electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Million ton</td>
<td>Million ton petrol equivalent</td>
</tr>
<tr>
<td>Crop residue</td>
<td>22.5</td>
<td>9</td>
</tr>
<tr>
<td>Animal droppings</td>
<td>8.15</td>
<td>3</td>
</tr>
<tr>
<td>Waste water</td>
<td>4.30</td>
<td>.86</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>6.6</td>
<td>1.65</td>
</tr>
<tr>
<td>Industrial waste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>41.55</td>
<td>14.51</td>
</tr>
</tbody>
</table>

1.3 Municipal solid waste:

The average compositions of the municipal solid wastes that were presented in figure 1. More than 77% of municipal solid waste are an organic waste and can be used to produce biogas. Which indicate the high potential of landfill gas generation.

The total municipal waste production in 2013 was above 20 million ton/year. [2]
1.4 Actual data from the only working landfill in Egypt

The governorate of Alexandria assigned ONYX (the company responsibility for waste collection in Alexandria) to open a new landfill in HAMMAM to work with the existed landfill in BORG EL ARAB. ONYX with its subsidiary VEOLIA agreed to participate with a project in partnership with Alexandria governorate, and the project will be implemented through CDM mechanism, and contribute to the climate change reduction by decreasing greenhouse gas emission. [3]

After 25-1-2011 revelation in Egypt, VEOLIA left the project and cancelled all agreements Alexandria governorate. Even so, HAMMAM landfill is still working and it is the only landfill in Alexandria. Most of Alexandria wastes were buried there for the time being. The gas extraction system was installed only in seven cells and started working in 2004 until now. The amount of buried waste in table 1 and the actual landfill gas extracted from HAMMAM landfill (figure 1). Data was taken from El Hammam landfill management.

The emission profile is like the typical landfill production graph (figure 3) [4]. EL HAMMAM landfill site was equipped with blower unit to extract Landfill gas with 1000 m3/hr. capacity; the pumping unit reached it is maximum capacity in April 2010. The unit is switched with another unit from BORG EL ARAB landfill fill with a capacity of 2500 m3/hr. capacity and started to extract the accumulated landfill gas and reached it is steady state flow in 2014. The years 2014 and 2015 have the same flow rate, which indicates the steady landfill production phase. [Hammam landfill management]

The project design estimate Gas collection efficiency is 70% [3]. Which were acceptable (figure 2) [4] and the calculation of this percentage will be done in modeling section.
Table 2, Amount of waste buried in Hammam Landfill site, Source: Hammam landfill management

<table>
<thead>
<tr>
<th>Year</th>
<th>Waste buried in TONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>307,180</td>
</tr>
<tr>
<td>2005</td>
<td>478,919</td>
</tr>
<tr>
<td>2006</td>
<td>410,844</td>
</tr>
<tr>
<td>2007</td>
<td>528,806</td>
</tr>
<tr>
<td>2008</td>
<td>550,000</td>
</tr>
<tr>
<td>2009</td>
<td>550,000</td>
</tr>
<tr>
<td>2010</td>
<td>550,000</td>
</tr>
</tbody>
</table>

Figure 2, Actual landfill gas production from El Hammam landfill, Source: Hammam landfill management
Figure 3, Gas Collection Recovery, the World Bank – ESMAP, Handbook for the Preparation of Landfill Gas to Energy Projects in Latin America and the Caribbean
1.5 Experimental Work

The objective of the experimental work has to decide how much landfill gas can be obtained from one ton of municipal waste. This parameter called biochemical methane potential (BMP). Sample weight been chosen to be 500 gram. It will be easier to control the environment around this sample and for the observation.

The composition of the sample is exactly as the composition of actual municipal waste. Table 2 shows the composition of the municipal waste in Cairo [5]. Most municipal waste in Egypt is similar to this composition [6].

An accurate scale was used to prepare the required composition. Three Samples were prepared. With the cooperation with Dr. Randa Osman (Associated professor in the chemical department working in National Research Center).

Three samples were prepared in three reactors (figure 4). The first sample was filled with municipal waste only. Second sample was filled with municipal waste and water. Third sample was filled with municipal waste and water and 25-gram cow dung (figure 5). The purpose of adding water and cow dung is to accelerate the digestion process. The fourth reactor with 25-gram cow dung was prepared only to know if it would produce any gas so we can subtract it from the quantity produced from the third sample. Samples were settled in water path to keep the water around the reactors at 35 C° (figure 6).

The above four reactors were connected to beakers by hoses. Beakers were used to collect and measure produced gas. All figures were taken while preparing the experiment (figure 7, 8).

Table 3 - Approximate municipal waste composition in Egypt, source: waste problem report (2012)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Waste</td>
<td>55%</td>
</tr>
<tr>
<td>Paper and carton waste</td>
<td>12%</td>
</tr>
<tr>
<td>Wood waste</td>
<td>5%</td>
</tr>
<tr>
<td>Textile</td>
<td>2%</td>
</tr>
<tr>
<td>Park waste</td>
<td>1%</td>
</tr>
<tr>
<td>Plastics</td>
<td>9%</td>
</tr>
<tr>
<td>Inert materials (glass, metals...)</td>
<td>16%</td>
</tr>
</tbody>
</table>
Figure 5 - Municipal waste in lab scale reactor.
Figure 6 - Measuring 25-gram cow dung

Figure 7 - the four sample in water path at 35°C
Figure 8 - Beakers used to measure the quantity of produced gas

Figure 9 - Reactors and hoses connected to Beakers
1.5.1 Results

Gas production data were collected over 77 days until the third sample production was dropped near zero. After that, the experiment was terminated although sample 1 and 2 were still producing gas. It was very hard to complete the experiment because the lab was busy with other experiments and it was going to take a lot of time more than 77 days. Still, results for sample 1 and 2 were recorded until the experiment was shut down and analyzed. The results of each sample are as follow:

1.5.1.1 Sample 3 (municipal waste with water and cow dung)

The highest-level production was at day 1 of the experiment (figure 9). The production rates were fluctuating. This is mainly because the gas was collected in the backers under its own pressure. No vacuum pump was used to extract the gas. It has gone out naturally to the beaker and the reactor shape was vertical so there was always some trapped gas that was accumulated and then released at once.

The total accumulated gas is 70,500 milliliter produced over 77 days (figure 10).

The cow dung sample (without the municipal waste) produced 100 milliliter-only and should be deducted from the total accumulated gas production. Nevertheless, its percentage is very small comparing to the total gas produced. The total gas produced after deduction is 70,400 milliliter.

1.5.1.2 Sample 2 (municipal waste with water only)

This sample showed a lower rate of gas production but with the same trend for accumulated gas production. The maximum production was at day 1 (figure 11). The time required to complete the fermentation process is longer and that is due fewer enzymes and microorganisms. Likewise, we can conclude that cow dung accelerates the fermentation process.

The total accumulated gas production is 45,950 milliliter over 77 days (figure 12).

As said above the experiment was shut down and no further data was recorded.

1.5.1.3 Sample 1 (dry municipal waste)

The production rate for the dry sample is much lower than the other samples, and that is due less humidity that increases the speed of fermentation process. The maximum daily production rate had achieved on day 16 (figure 13). The accumulated gas production trend is similar to the other samples.

The total gas produced is 15,575 milliliter over 77 days (figure 14). No more data was recorded.
Figure 10 - municipal waste with water and cow dung gas production

Figure 11 - municipal waste with water and cow dung accumulated gas production
Figure 12 - municipal waste with water only gas production

Figure 13 - municipal waste with water only accumulated gas production
Figure 14 - dry municipal waste sample gas production

Figure 15 - dry municipal waste sample accumulated gas production
1.9 Discussion

From the results of the three samples, conclusion can be summarized as follow:

- Landfill gas that can be produced from 1-ton municipal waste is approximately 140 m³/ton municipal
  waste.
- The water and cow dung sample were the fastest to be fermented due to the existence of microorganisms
  in the cow dung. Water also provides a very suitable environment for microorganisms.
- The water only sample was the second fastest regarding the fermentation process. Because of water, that
  provides the suitable environment for the fermentation process.
- The dry sample is very slow, and requires a lot of time to be fermented.

More experiments and observations need to be done to determine the accurate decaying rate. Determination
of accurate decaying rate will help to produce more modeling results and the prediction of landfill emissions
and amount of energy generation.

Although the research encourage wider implementation of landfilling as a solution of municipal waste.
Nevertheless, I want to stress here it is not the only solution. Other solution must be implemented in parallel.
RDF and Recycling are promising rising technology that established their position in Egyptian market.
As seen from the above experiment and Modeling, A rule of thumb was developed specifically for Egypt.
The waste composition is nearly similar all over Egypt with only minor variation. The developed rule of
thumb can be applied anywhere in Egypt with reasonable efficiency.

1.10 Conclusion

Using landfill gas emissions for electricity production have several benefits, which can be summarized it as
follow:

- Creating revenues from “waste”.
- Significant emission and risk reduction.
- Landfill management improvement.
- Renewable energy production.
- Reduction of greenhouse gas emission (methane).
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- Improvement of local air quality.
- Improved living conditions.
- Stimulation of local economy.
- Creating new jobs and business opportunities.
- Replacement of fossil fuel by renewable energy.

Although of all of these benefits, the government and the ministry of environment, have to set regulation for
landfills. Until now, Egypt has no regulations or rules to determine how you should dispose municipal
waste. We have in Egypt only one controlled landfill. The other landfills are just dumpsites or semi-
controlled landfills. [1]

When landfills close, it can be turned to gardens. With some planning, we can use the gardens in the new
cities, plans to implement small cells and produce electricity. This will decrease the costs for infrastructure
for new cities and supply clean and green energy.
References

1- The Egyptian cabinet information and decision support center The Future of Alternative Energy in Egypt (2009)

2- Ministry of environment annual report (2013)

