International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-4 Issue-1, October 2014

# The Assessing and Prediction of Biogas Production and Dissemination Rate in Ardebil City Landfills and Chemical Analysis of Obtained Biogas

**Ali Shamel, Reza Alayi, Leila Abbaszadeh**

***Abstract—the main purpose of making municipal landfills and produced biogas collecting is to prevent the emission of greenhouse gases such as Methane and also using the heating value involved in this gas. A propose to bury Ardabil's wastes and the analysis of produced gases in terms of quality and quantity is presented in this research. In recent years, Landfill projects include equipments to control, gas transmission and also using the biogas energy. Landfill gases that are called LFG are obtained from performing a series of biochemical reactions, in anaerobic conditions, on organic dissoluble matters available in the waste; these gases are Methane, Carbon Dioxide and Hydrogen gases, Hydrogen Sulfide and volatile organic compounds. The assessing and prediction of biogas production and dissemination rate is important in Landfill designing and successful using of produced gases as renewable energy sources. Produced gases in landfills, after extraction and filtration can directly supply energy needed for industry such as lighting, fuel needed for gas turbines and electricity producing generators and even they can be used to set up simultaneous production units of heat and power. In the first part of this study, the explanation of the methods, equations and used assumptions are explained. In the second part, Ardabil city's landfill conditions have been introduced and in addition to that, the amount of waste and other information contained on this site has been evaluated. In this research, the waste of Ardabil city is studied and the gases resulting from landfill are analyzed carefully, using LANDGEM software. After running the LANDGEM software concluded. During operation of the project the emissions gases about 50% is the methane gas.***

***Keywords— Biogas, Landfill, waste, LFG, Methane, Renewable energy***

## I. INTRODUCTION

One of the main methods of waste eliminating in the world; and in Ardabil as an example is landfill; as a result of biodegradation of organic matters, available in wastes, some types of gases are produced that Methane and Carbon Dioxide gases are the majority of them. Due to their greenhouse effects, these gases are being considered as environmental pollution sources. Therefore, in order to understand the emission level of these gases from the Landfill and their effects, further studies are essential to develop effective strategies in their controlling and exact management.

**Manuscript published on 30 October 2014.**
***** Correspondence Author (s)
**Ali Shamel**, Department of Chemistry, Islamic Azad University Ardabil Branch, Ardabil, Iran.
**Reza Alayi**, Department of Mechanics, Islamic Azad University Ardabil Branch, Ardabil, Iran.
**Leila Abbaszadeh,** Department of Chemistry, Islamic Azad University Ardabil Branch, Ardabil, Iran.



If household waste burial is done in the absence of oxygen, the organic portion of the waste will be fermented and as a result, a mixture of Methane, Carbon Dioxide, Hydrogen, Nitrogen gases and small amounts of Chlorine and Fluorine and moisture will be produced. Usually gas production starts after two months of burial and continues up to 100 years. In this method, gas production wells have been drilled with different distances and Polyethylene perforated pipes are located within the wells and their around are filled with sand. Then, the well's head is completely isolated from outside environment and valve is installed on the system. Gas transmission and collected pipelines connected to the said valves and the produced gas is extracted after passing through the system to remove moisture. The Landfill gas can be used in the electricity generation systems; such as diesel generators, gas turbines or micro-turbines. And the direct usage of landfill gas in boilers with burning or local injection into the natural gas network is also possible.[1]-[4]

In economic terms Landfill is much more affordable than incinerating waste or converting into fertilizer. Hence, in most countries, landfill sites were constructed that all of them were accomplished uncovered due to non-academic performance and they had been smelly places. With the advancement of science, in last 20 years, special provisions were imposed on all countries by U.S. Environmental Agency to build scientific landfill sites. [3]-[7]

## II. Method and Materials

### A. The main effective factors of biogas production in landfill method

#### 1. Temperature of fermentation environment

Usually, biogas sets can work in 30 to 70°C temperature that is Mezofilic Bacteria's' activity tract, however, its optimum temperature is 30°C. The environment may be acidic at temperatures higher than 70°C and bacteria's are destroyed at lower temperatures. Thus, Methane generating bacteria's are quite sensitive to rapid fluctuations of temperature and have negative impact in biogas production.

#### 2. The acidity or pH of Matters

Methane generating bacteria are very sensitive toward the environment pH and these bacteria and other anaerobic organisms' activity is possible in the environment with 6.7 to 7.2 pH .


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Then, pH should be kept around 5.7 to 7.7 ; if the pH is less than 5.5, Methane generating bacteria's life will have disturbances and so the Methane bacteria will be inactive ,then, methane production will be stopped.

### 3. The ratio of Carbon to Nitrogen(C/N)

Anaerobic bacteria need Carbon and Nitrogen to survive and do their activities. Usually anaerobic bacteria use Carbon as an energy source to growth and Nitrogen to build their cell walls. The proportion of these materials is very important in controlling the interactions; the intake scale of Carbon is 30 to 35 times faster than Nitrogen; therefore, the C/N ratio of the raw materials is very efficient for the activity of the anaerobic bacteria, the fermentation speed up and subsequent to that Methane production. The Carbon and Nitrogen ratio is ideally about 25 to 30.

### 4. Humidity and required water scale

The raw materials water content that should be fermented in has been constituted about 90% of the total weight of the materials. Too much increasing or decreasing the materials' humidity in fermentation impacts on gas production.

### 5. The degree of concentration of the materials

It is necessary to turn the materials into a watery solution in order to absorbing organic matters by bacteria. More concentration causes more stickiness and prevents the growth of bacteria and less concentration causes solution to be layered. [12]- [13]-[14]

### 6. Shelf-life in the landfill

Retention time is very important because if input materials don't stay within the landfill and the process of digestion and fermentation doesn't complete so, any biogas will not produce. Gas production will increase if the increase. In other words, more retention time more biogas production.

### 7. The solution steady

Keeping steady the solution in terms of concentration and temperature, has positive effect on reproduction rate of bacteria. Keeping steady the solution will instigate more bacteria's and subsequent to that gas production will be sti

## B. Various techniques of landfill gas collection

Generally, collection systems of landfill gas can be divided into two categories:

(A) Active collection systems (Active)

(B) Passive collection systems (Passive)

## C. The differences between active and passive gas collection systems

Active gas collection systems use mechanical blower or compressor in order to create the pressure gradient for extracting the landfill gas. While in passive gas collection systems, natural pressure gradient produced between internal gas pressure within the landfill and ambient air pressure cause gas transmission and extraction. Selecting the kind of the gas collection system for a special landfill depends on the existed characteristics and limitations. Usually, the active collection system with vertical well is used in cellular filling form landfills. The advantage of using this system is its lower costs. The trouble is its hard installing so that it makes very difficult to work on landfill and any moment, there is possibility of falling heavy equipments into the landfill.

The active gas collection system with horizontal channel is used in landfills that wastes are filled in layers. The advantage is that it requires no drilling and the installation process is simple. And the disadvantages of this system are the possibility of filling the canal by Leach ate and fracture probability in lower layers of the collection system. Conventional PSS comprising cascade connected [5]-[9]

## D. Affecting factors of the landfill techniques efficiency

Components of the waste allocation

Testing the kind of waste specifies carefully different components of the waste. This analysis is used to determine the waste production process and the percentage of each component in its composition. According to the research objectives, the materials of this study are divided into 12 groups. Among these components, only the corruptible materials need chemical analysis. Because the nature of other components in waste has a fixed composition . Thus, other information about any composition such as moisture, volatile solids, fixed Carbon and combustible materials are available through the amount of the fundamental elements. Anyway, this information's are available in different sources. Approximate analysis and energy levels in various combinations of waste are presented in Table1. [8]

| Special waste | Rubber | Glass | Construction debris | Metal | Textiles | Wood | Plastic | Paper | Corruptible materials | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.35 | 0.77 | 1.76 | 1.50 | 2.34 | 3.42 | 1.71 | 11.87 | 3.71 | 71.57 | Winter |
| 1.22 | 0.61 | 1.81 | 1.72 | 2.40 | 3.15 | 1.61 | 12.02 | 3.61 | 71.85 | Spring |
| 1.26 | 0.75 | 1.66 | 1.65 | 2.27 | 3.23 | 1.78 | 12 | 3.82 | 71.58 | Falling |
| 1.28 | 0.71 | 1.74 | 1.62 | 2.34 | 3.27 | 1.7 | 11.96 | 3.71 | 71.66 | Average |

**Table 1: Physical analysis of municipal solid waste in Ardabil**

Corruptible materials are main components in waste composition. The results of the analysis show that the average percentage of perishable wastes is 71.66 %. So, due to the high percentage of perishable materials the waste of the zone has good potential for landfill implementation.


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**Table 2: Final analysis of samples of solid waste**

| % Db | | | | | | materials |
|---|---|---|---|---|---|---|
| Ash | S | N | O | H | C | |
| 5 | 0.5 | 2.5 | 38 | 6 | 48 | Food stuffs waste |
| 6 | 0.2 | 0.3 | 44 | 6 | 43.5 | Paper |
| 10 | - | - | 23 | 7 | 60 | Plastic |
| 98.9 | changing | 0.1 | 0.4 | 0.1 | 0.5 | Glass |
| 90 | changing | 0.1 | 3.4 | 0.6 | 5 | Metals |
| 3 | 0.2 | 5 | 30 | 7 | 575 | Textiles |
| 68 | 0.2 | 0.5 | 2 | 3 | 26 | Ashes and Dust |

**Table 3: Qualitative characteristics of produced waste in Ardabil (summer)**

| sample : city wastes (perishable materials | |
|---|---|
| Sample place : inside the city | |
| 07/5 | acidity |
| 15/71 | moisture percentage |
| 21/67 | C/N |

**Table 4: Qualitative characteristics of produced waste in Ardabil (winter)**

| sample : city wastes (perishable materials | |
|---|---|
| Sample place : inside the city | |
| 58.5 | acidity |
| 2.56 | moisture percentage |
| 66.58 | C/N |

### E. Prediction methods of waste in future years

- predictions based on population
- predictions based on the tonnage of produced waste

### Predictions based on population

It is necessary to evaluate and forecast Ardabil city in terms of population in order to understand its waste status in future years. According to existed statistics in Statistical Center of Iran, Ardabil's population changes in past 30-years period has been described below in the table5 [6]

**Table5: Population and average annual growth in province [6]**

| Average annual growth (%) | population number | year |
|---|---|---|
| - | 777123 | 1355 |
| 9/2 | 1033568 | 1365 |
| 2 | 1141625 | 1370 |
| 46/0 | 1168011 | 1375 |
| 5/0 | 1228155 | 1385 |

### F. Ardabil County's population forecasting in existed situation

Choosing the method of population forecasting depends on the quantity and quality of available statistics. There are many methods to forecast a population for example: Exponential method. Exponential method is most popular method to calculate the population in Iran. Most of the statistical agencies use this method. In this method, coefficient of population growth has been used as an exponential relation to calculate the population. The following formula is used for this purpose:

$$P_n = p_0 (1+r)^n \qquad (1)$$

$P_n$ = the desired year's population
$p_0$ = Current population
r = Annual coefficient of growth in percentage
n = period of project...

**Table 6: Ardabil's population forecasting in 2026**

| Population in 2026 | Population in 2009 | city |
|---|---|---|
| 623139 | 418890 | Ardabil |

### G. Waste generation per capita in Ardabil city

With regard to about 350 tons of wastes generated per day in Ardabil and also 420,000 peoples of its population in 2009, the amount of waste per capita in Ardabil is equivalent to 833 grams per day which is consistent with the announced standards. [8]

**Table 7: Waste generation per capita in Ardabil's cities**

| Household per capita | Total per capita | Name |
|---|---|---|
| 774g | 833g | Ardabil |

The amount of produced solid wastes in developing countries increases additionally. At the end of each decade, it becomes nearly twice. Rapid population growth in the cities of the developing countries is one of the reasons of this increase that is averagely between 3 to 6 %. With regard to the population growth and waste generation per capita, as population increases, waste generation statistics will increase.

### Predictions based on the tonnage of waste

We suppose Ardabil's Landfill to be established in 2006 and 20-years projection period for using that, the amount of entered waste into this landfill is calculated by EVIEWS software from 2006 to 2025, with regard to the population growth, per capita waste generation for any person, waste tonnage statistics in previous years (according to municipality report), physical analysis and the percent of wastes (spoilable materials, paper and wood) effective in landfill methane production.

**Table 8: Entered waste into the landfill in establishing and ending years**

| ending year(2025) | establishing year(2006) | year |
|---|---|---|
| 399840.6 | 83965.1 | Amount of entered waste into landfill (ton) |

Ardabil's landfill is located in TALEB GHESHLAGHI zone and every day, all of the produced wastes in Ardabil city are transferred to this site. This place is at a distance of 26 km of outside the Ardabil city.


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### H. Investigating the possibility of reducing methane pollution produced from municipal solid waste landfill in Ardebil using Land GEM software

By selecting landfill option for eliminating waste in order to reduce Methane emissions from environment, and also making possible energy generation and using that in Ardabil city; Methane pollution reduction from municipal solid waste landfill has been considered in this study. In order to achieve these objectives, estimating the amount and process of gas production in this landfill has been done using Land GEM software and the potential of the energy production of Methane has been calculated. Then, we discussed about Methane as an energy source to be effective in pollution reduction and its economic efficiency.

## III. LAND GEM SOFTWARE INTRODUCTION

Land GEM software package is prepared by Technology Control Centre Environmental Protection Agency America and can be used as an automatic estimating tool for modeling gas emissions from municipal solid waste landfill. This software package can calculate the amount of produced landfill gas and also is able to estimate the amount of 46 air pollutant and volatile cases in landfill. [2]-[7]

In this study, Land GEM software is used as a tool for estimating gas emissions from landfills. This software uses an equation to estimate the amount of Methane that is expressed as follows:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10}\right) e^{-kt_{ij}} \qquad (2)$$

QCH4 = annual generated Methane over the calculation year (m3/yr)

i = timer (1year)

n = (calculation year) - (year of initial waste entrance)

j = timer (0.1yr)

k = generated Methane content (1/ yr)

Lo = potential of Methane generation (m3/Mg)

Mi = mass of entered waste in the I the year (Mg)

tij = age of the j the section of waste mass Mi entered in the I the year

According to the mathematic equation used in this model, information's such as amount of waste available in landfill, number of its beneficiary years, potential of Methane production and Methane production constant are necessary.

### Estimated potential of Methane gas generation in Ardabil's Landfill (Lo)

The obtained amount of L0 of each ton of wastes on the basis of waste composition, Landfill status in Iran and environmental conditions in accordance with IPCC (Interstate Committee on Climate Change) has been calculated in 1996 according to the following expression:

$$L0=MCF\times DOC\times DOCf\times F\times 16/12\times (OX-1) \qquad (3)$$

These parameters are listed below:

DOC: The content of degradable organic carbon in the waste that is an essential part of gas generation calculations=3.0

MCF: correction factor of Methane generation=8.0

DOCf: This factor is a percentage of organic matters that can converted into Methane and Carbon Dioxide=68.0

F: percentage of Methane available in landfill gas that is presented 61.1% in sources.

OX: the extent of oxidation in landfill layers

So the calculated amount of L0 for Ardebil municipal waste is 170 ( m3/tone). [10]- [11]

### The constant of the Methane generation rate (k)

The constant of the Methane generation rate (k) is determiner of landfill's gas production regime that presents; more (K) more gas production. In other words, increasing the value of (k) causes more gas production at a certain time and a certain amount of waste in the same conditions. (K) Ranges will be considered between 0.003 to 0.21. And hence, the amount of Methane production rate will be dependent to existed moisture in Ardabil's waste (on average 87% of the waste mass), temperature (18-23 °C in the wastes mass existed in landfill) and PH (5.3). Considering all above conditions for Ardabil, the k is 0.05 (1/yr). [14]

## IV. RESULTS

According to the available data and using Land GEM software, gas production process has been obtained over the time. In this software the production of 4main emissions of Methane, Carbon Dioxide, Total gas and non-Methane organic compositions have been calculated and expressed by charts and tables.

**Table 9: Amounts of landfill emissions gases**

| Year | Total gas | Methane | Carbon dioxide | NMOC |
|---|---|---|---|---|
| | m3/year | m3/year | m3/year | m3/year |
| 1385 | 0 | 0 | 0 | 0 |
| 1386 | 1/396E+6 | 6/979E+5 | 6/979E+5 | 5/583E+3 |
| 1387 | 2/836E+6 | 1/418E+6 | 1/418E+6 | 1/134E+4 |
| 1388 | 4/589E+6 | 2/295E+6 | 2/295E+6 | 1/836E+4 |
| 1389 | 6/566E+6 | 3/283E+6 | 3/283E+6 | 2/627E+4 |
| 1390 | 8/695E+6 | 4/347E+6 | 4/347E+6 | 3/478E+4 |
| 1391 | 1/100E+7 | 5/500E+6 | 5/500E+6 | 4/400E+4 |
| 1392 | 1/347E+7 | 6/736E+6 | 6/736E+6 | 5/389E+4 |
| 1393 | 1/610E+7 | 8/051E+6 | 8/051E+6 | 6/441E+4 |
| 1394 | 1/889E+7 | 9/443E+6 | 9/443E+6 | 7/554E+4 |
| 1395 | 2/181E+7 | 1/091E+7 | 1/091E+7 | 8/725E+4 |
| 1396 | 2/488E+7 | 1/244E+7 | 1/244E+7 | 9/951E+4 |
| 1397 | 2/807E+7 | 1/404E+7 | 1/404E+7 | 1/123E+5 |
| 1398 | 3/139E+7 | 1/569E+7 | 1/569E+7 | 1/256E+5 |
| 1399 | 3/483E+7 | 1/741E+7 | 1/741E+7 | 1/393E+5 |
| 1400 | 3/837E+7 | 1/919E+7 | 1/919E+7 | 1/535E+5 |
| 1401 | 4/203E+7 | 2/102E+7 | 2/102E+7 | 1/681E+5 |
| 1402 | 4/579E+7 | 2/289E+7 | 2/289E+7 | 1/832E+5 |
| 1403 | 4/964E+7 | 2/482E+7 | 2/482E+7 | 1/986E+5 |
| 1404 | 5/359E+7 | 2/679E+7 | 2/679E+7 | 2/144E+5 |
| 1405 | 5/762E+7 | 2/881E+7 | 2/881E+7 | 2/305E+5 |


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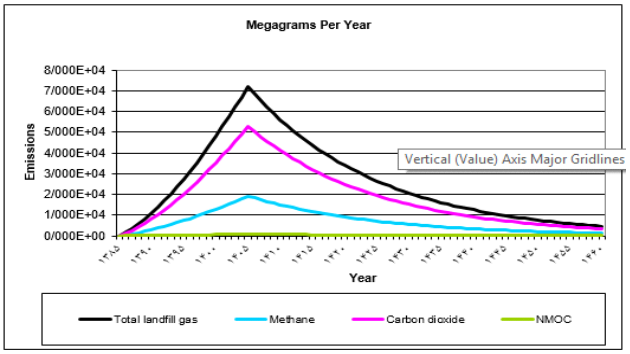
**Figure 1: Curve for Methane emission k=0.05 1/ y و $L_0$=170 m3/tone**




The production process of Methane contaminants, Carbon Dioxide, non-Methane organic compounds and Total gas in Ardabil's landfill shows that due to the influence of moisture on Methane emissions and climatic variability in Ardabil, selecting a suitable location for the project is a debatable points.

Due to significant volume of gas extraction from the landfill, we can achieve a renewable energy source in addition to capability of removing environmental pollutants. Also, the environmental problems associated with landfill gas emissions, including the creation of unpleasant odor, air pollution and groundwater contamination have been eliminated significantly. This kind of energy is the only form of renewable energy which is made by removing the infection. Choosing the best using form of landfill biogas energy depends on the type and number of produced energy consumptions, project costs and etc. Based on the analysis of the different cities' waste, it is possible to produce a significant amount of biogas in the country. [4]

**Usability of obtained Methane to Electricity generation**

Each cubic meter of biogas can produce 5.22 Kilowatt/hour Electricity. In addition to providing some country's required energy, developing biogas powerhouses can be an effective step towards a massive crisis caused by wastes and environmental emission sins reduction that will have dramatic social and economic effects. For example, , according to the volume and amount of Methane produced in Ardabil city's landfill, there was the production potential for 54752.5 MWH electricity in 2012 in Ardabil city which in comparison with total annual used electricity in Ardabil city, that would provide % 9.44 of total city consumption.

## V. CONCLUSION

Biogas is a gas that is produced from urban and industrial waste. One of the methods to produce biogas (methane) is a method of landfill. In landfill method, the two methods methane gas can be collected of active and passive. In this paper, active the method used to collect for methane gas. Because the project has highly reliability of EVIEWS software was used to predict the urban waste by the year 2026. After running the LANDGEM software concluded. During operation of the project the emissions gases about 50% is the methane gas. Methane gas can be used in cases such as electrical power generation, Electricity production can from methane, about 9% of electricity demand responsive Ardabil city.

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