EVALUATION OF THE RESULTED ENERGY FROM EL HAMMAM SANITARY LANDFILL

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ABSTRACT

The study was conducted in El Hammam sanitary landfill at Alam Nayel to evaluate the resulted energy by measuring the emitted gas production, methane percent as one of the most important gas components, produced energy, energy consumption in landfill operation and finally leachat flow rate to optimize energy production from landfill. The landfill produces large amount of gas, which is burned without using it as a source of energy. The gas can be used to generate electricity or to be pumped in to pipeline gas to reduce energy costs and greenhouse gas emissions. The cumulative values of the produced gas, methane, thermal energy and electric energy were 1.93 million m^3, 768,226 m^3, 7665.2 M.W.h and 2682.82 M.W.h respectively after 1860 day. The landfill electric consumption was about 43 M.W.h/year, which is generated by 11 kW diesel engine, consumes about 17,520 liter/year and produce CO_2 emission of about 43,800 kg/year.

Key words: *solid wastes, landfill gas, thermal energy, leachate.*

INTRODUCTION

The management of solid wastes is considered one of the biggest problems in Egypt because it affects all aspects of citizen's life.

Zaki et al. (2013) reported that the amount of generated solid wastes in Egypt is from 0.3 to 0.8 kg/day/capita, with an annual growth of 3.4%. The total annual generated solid wastes in Egypt have increased more than 36% since 2000, to the current level of 20.5 million ton per year in 2013. In addition, there is 6.2 million ton/year industrial waste including 0.2 million ton of hazardous waste and 23 million ton/year of agricultural waste. El Beri, (2013) reported that the Egyptian municipal solid waste consists of 60% organic waste, 11% paper, 3% glass, 12% plastic, 2% textiles, 2% metal and 10% other.

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Al Seadi et al. (2008) reported that the increase in production of organic wastes is considered one of the main environmental problems, so that the sustainable waste management as well as waste prevention has become major political priorities, representing an important share of the common efforts to reduce pollution and greenhouse gas emissions and to mitigate global climate changes.

Egypt is the second largest dry natural gas producer in Africa. However, the production of the energy in Egypt has been steadily declining since 2009 and in 2012 reached 82,046 kilo tonne of oil equivalent. This is due to shortages in natural gas and oil production. The shortages have led to frequent electricity blackouts (Iea, 2016).

Ehrig et al. (2011) reported that landfill gas is a complex gas mixture created by the action of microorganisms in a landfill, which consists of methane (CH_4), carbon dioxide (CO_2) and trace gases such as hydrogen and sulphide.

The landfill gas is the result of three processes: 1- evaporation of volatile organic compounds, 2- chemical reactions between waste components, 3-microbial action. The first and the second processes strongly depend on the nature of the waste. The main process in most landfills is the third process which the anaerobic bacteria decompose organic waste to produce biogas. Formation of methane and CO_2 need about six months after depositing the landfill material. The production of gas reaches a maximum at about 20 years, then declines (UEIA, 2015).

Sullivan (2013) reported that landfills are the third largest source of human-made methane emissions in the United States. The gases produced within a landfill can be used in various ways. The landfill gas can be used directly on site by a boiler or any type of combustion system, providing heat. Electricity can also be generated on site by use of steam turbines, or fuel cells.

The landfill gas can be sold off site and sent into natural gas pipelines. This approach requires the gas to be processed into pipeline quality, e.g., by removing various contaminants and components (Sethi, 2013). The efficiency of gas collection at landfills directly can be affected the amount of energy that can be recovered in case of closed landfills (those no longer accepting waste), the collected gas produces more efficiently than open landfills (those that are still accepting waste) (EPA, 2013).

The research was carried out:

1- To evaluate landfill gas quality and production.
2- To determine a blueprint for produce electric and thermal energy from gas.
3- To determine a blueprint for reduce greenhouse gas emissions from the landfill.

MATERIALS AND METHODS

The research was done at El Hammam sanitary landfill in Alam Nayel, Alexandria. The chemical analysis was conducted in the laboratory of Soil and Agricultural Engineering dept., Faculty of Agriculture Saba Basha, Alexandria University.

1- Location and technical specification of landfill

El Hammam landfill has been established for the disposal of waste collected from Alexandria, which is located 80 km in the south west of Alexandria city (30.754 N, 29.417 E) as shown in Fig. (1). The surface area of the landfill is 53.76 ha with cells height about 25-30 m. The Landfill started in 2003 to receive about 510,000 ton of waste every 6 months (Onyx, 2006).

Fig. (1) : El Hammam landfill location.

The landfill consists of 11 cells, the cells from 1 to 7 equipped with biogas network, while the cells from 8 to 11 are not equipped with biogas network as shown in Fig. (2).

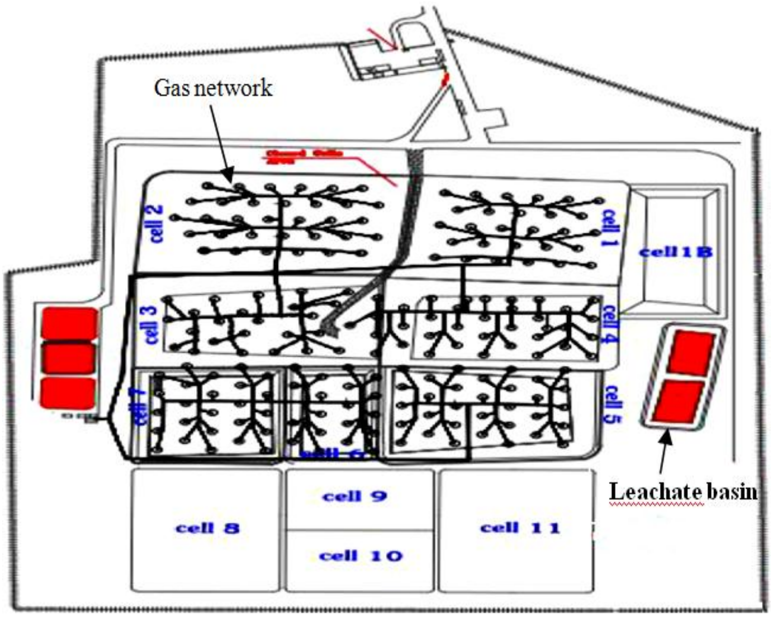

Fig.(2) : Diagram of landfill cells and gas network (1:20,000 scale).

The shape and the specification of each cell which include length, width, area and gas production are shown in Table (1) and Fig.(3). In order to increase methane percentage, a purification gas station was used to separate undesirable gases. The resulted liquid from waste decomposition in the cell is pumped towards leachate basins to vaporize the leachate by the sun. The leachate basins were isolated according to the environmental standards and technical specifications to protect the ground water.

Table (1). Cells dimensions and cumulative gas production (Onyx, 2006)

No of cell	Length, m	Width, m	Area, m^2	Cumulative gas production, m^3
1	204	190	38760	1,747,612
2	252	190	47880	2,158,815
3	233	100	23300	1,050,551
4	233	100	23300	1,050,551
5	166	156	25896	1,167,600
6	166	78	12948	583,800
7	233	166	38678	1,743,915
Total			210762	9,502,845

2- Sampling and analysis

Six leachate samples were collected randomly from leachate basins in El Hammam sanitary landfills and analyzed to assess their physiochemical characteristics and heavy metals concentrations as presented in Tables (2 and 3).

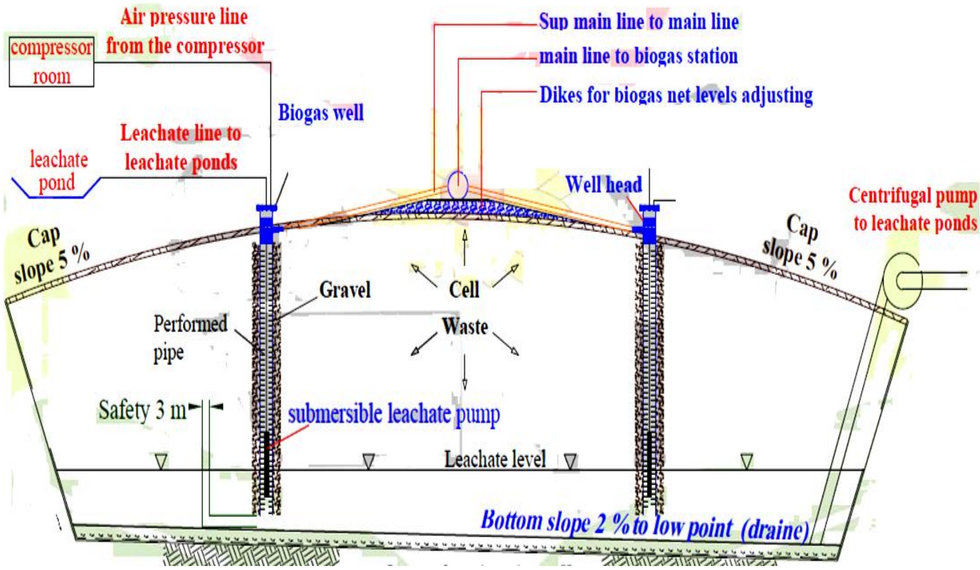

Fig.(3) : Diagram of cell cross section and gas network.

Table (2). Physical and chemical analyses of leachate samples.

Parameters	Unit	Min value	Max value
PH	–	7.1	7.9
Conductivity	µS/cm	34,680	41,944
Total dissolved solids	mg/l	23,853	31,221
Chlorides	mg/l	9523	16,196
Total suspended solids	mg/l	3265	14,355
Chemical oxygen demand	mg/l	12,253	16,260
Biochemical oxygen demand	mg/l	9620	11,700
Total nitrogen	mg/l	386	956
Ammonia-N	mg/l	192	415
Nitrate-N	mg/l	0.35	2.92
Sulfates	mg/l	296	723
Phosphates	mg/l	0.28	0.51

Table (3). Heavy metals concentrations at leachate samples.

Heavy metals	Unit	Min value	Max value
Nickel	mg/l	0.034	0.159
Lead	mg/l	0.009	0.023
Copper	mg/l	0.015	0.167
Manganese	mg/l	0.258	1.400
Chromium	mg/l	0.027	0.092
Cadmium	mg/l	0.002	0.261
Zinc	mg/l	0.339	0.969
Iron	mg/l	0.423	11.500

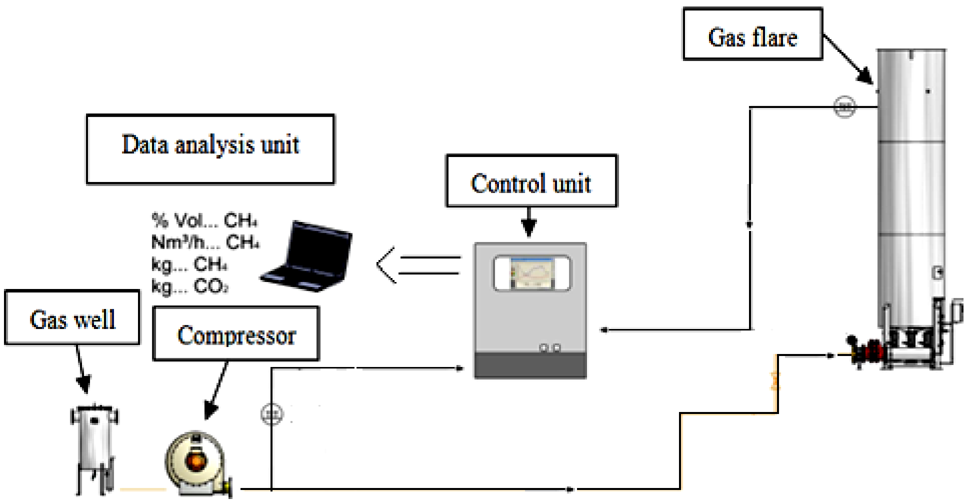

Fig. (4): CDM gas flare system.

3 - Instrumentation

3-1 (CDM) gas flaring system

The Clean Development Mechanism (CDM) system is a continuous monitoring with verifiable records that demonstrate methane destruction, which consists of:

A- Compressor for gas pumping from the well to the flare systems as shown in Fig. (4).

B- Control unit to measure biogas constituents, temperature, flow rate and automatic monitor gas flare.

C - Gas flare to burn gas and forwarding of gas quantity and combustion data.

3-2 A portable biogas analyzer (Landtec GEM 2000) was used to monitor landfill gas (LFG) extraction systems, flares, migration control systems and to measure the percentage of CH_4 (0-100%), CO_2 (0-100%), O_2 (0-25%), H_2 (0-1000ppm), NH_3 (0-1000ppm) and H_2S (0-10,000ppm) in the biogas as shown in Fig (5).

Fig. (5): Portable gas analyzer (Landtec GEM 2000).

3-3 The ENDRESS HAUSER volumetric flow meter as shown in Fig.(6) was used to measure the volumetric flow rate of a landfill gas, (m^3/h) with an accuracy of +/-0.01 at ambient temperature: from -20°C to +60°C and maximum pressure of 100 bar.

Fig. (6): ENDRESS HAUSER flow meter.

4- **Anaerobic biodegradation of municipal solid waste (MSW)**

The organic wastes start to undergo biochemical reactions, after MSW is landfilled. The natural organic compounds are oxidized aerobically in the presence of air near the surface of the landfill. The reaction is similar to combustion because the products are carbon dioxide and water vapor. However, the anaerobic digestion is the principal process in landfills, which takes place in three stages. In the first stage, the fermentative bacteria hydrolyze the complex organic matter into soluble molecules. In the second stage the molecules are converted by acid forming bacteria to simple organic acids, carbon dioxide and hydrogen; the principal acids produced are acetic acid, propionic acid, butyric acid and ethanol. Finally, in the third stage, methane is formed by methanogenic bacteria, either by breaking down the acids to methane and carbon dioxide as shown in the chemical reaction below (Themelis et al. 2006).

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2.$$

Methanogenesis

$$CH_3COOH \rightarrow CH_4 + CO$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O.$$

5- Methane production

The amount of methane production from the landfill can be calculated using the following equation.

Methane production, m^3/h =

Landfill gas production m^3/h x Methane percent in landfill gas

6- Energy production

The amount of thermal energy generated from the landfill gas can calculated using the following equation according to Surroop et al. (2011).

$$\mathbf{Eth} = \frac{\mathbf{FCH4 \times LHVCH4}}{\mathbf{3600}}$$

The amount of electrical energy could be computed using the following equation according to Surroop et al. (2011).

$$\mathrm{Eel} = \frac{\mathbf{FCH4 \times LHVCH4 \times \eta ef}}{\mathbf{3600}}$$

Where:

Eth - The thermal energy, kW.h.

FCH4 - Flow rate of CH4, m^3 /h.

LHVCH4 - Methane lower heating value of 36000 kJ/m^3

Eel- Electrical energy, kW.h

ηef - Electrical efficiency of 35%

RESULTS AND DISCUSSION

1- Landfill gas production

The relationships between daily and cumulative landfill gas production per m^3 and the time per day are shown in Fig.(7). In general the graph showed that the landfill gas production increases by increasing the time until reach the maximum value and then the production starts to decrease. The cumulative landfill gas production increases by increasing the time until reach the maximum value of 1.93 million m^3 after 1860 day for the total cells area and volume of 210,762 m^2 and of 5.26 million m^3 respectively. It was observed that the highest biogas production was 2598 m^3/day after 1296 day, while the lowest gas production was 198 m^3/day in the beginning of production. There are five stages of gas productions. The averages daily gas production were 429, 907, 1366, 2389 and 1632 m^3 at 680 day for the first stage, 324 day for the second stage, 197 day for the third stage, 97 day for the fourth stage and 563 day for the fifth stage respectively as presented in Tables(4).

It was observed that the first stage is the lowest gas production because it is aerobic fermentation stage, which the aerobic microorganisms deplete oxygen and produces nitrate in leachate. Whereas the fourth stage is the highest gas production because solid waste was at full degradation and oxygen is no longer present in the landfill.

The gas will continue to be emitted for 20 or more years if a landfill receiving higher than average amounts of domestic animal waste. (Crawford and Smith 1985).

A polynomial equation was determined to calculate cumulative gas production, m^3/day after any period of time, day as shown in Fig.(7).

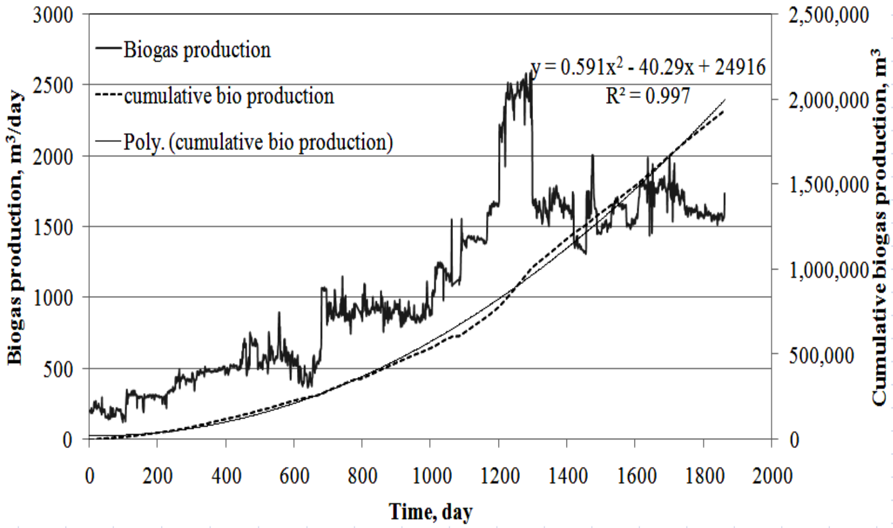

Fig. (7): Daily and cumulative landfill gas production.

1-1 Factors Affecting landfill gas production

1-1-1Waste Composition

There is no classifying unit at El Hammam sanitary landfill to classify the municipal solid waste into organic and inorganic wastes which lead to decrease gas production. Some types of organic waste contain nutrients, such as sodium, potassium, calcium, and magnesium, which activate bacteria, while some wastes contain salt concentrations that harm bacteria and decrease gas production (Crawford and Smith 1985). The more organic waste present in a landfill, the more methane is produced by bacterial decomposition, so to increase gas production at El Hammam sanitary landfill a classifying unit should be used to separate inorganic wastes from solid wastes.

1-1-2 The content of oxygen

The oxygen is available inside loosely buried waste, so that aerobic bacteria consume oxygen and produce carbon dioxide and water, while if the waste is highly compacted. methane production will begin earlier as the aerobic bacteria are replaced by anaerobic bacteria (Tecle et al. 2008), so the organic wastes at El Hammam sanitary landfill should be highly compacted to start the methane production early.

1-1-3 Moisture Content

The moisture content of organic wastes is important factor affecting on gas production. The moisture content of 40% or higher increases gas production because moisture encourages bacterial growth and transports nutrients and bacteria (Tecle et al. 2008).

The leachate can be used to increase wastes moister content by pumping it inside the landfill.

1-1-4 Temperature

The landfill temperature is controlling bacterial activity and gas production. The best temperature range for landfill is between 25 and 45°C to increase bacterial activity, while temperature below 10°C decreases bacterial activity dramatically (Tecle et al. 2008). Weather changes have a far greater effect on gas production in shallow landfills. A capped landfill usually maintains a stable temperature, maximizing gas production. An automatic control unit with solar heating system can be used to control the temperature of El Hammam sanitary landfill without using extra electric energy.

1-1-5 Age of Refuse

Landfills usually produce appreciable amounts of gas within 1 to 3 years. Peak gas production usually occurs 5 to 7 years after wastes are dumped. Almost all gas is produced within 20 years after waste is dumped; however, small quantities of gas may continue to be emitted from a landfill for 20 or more years (Tecle et al. 2008).

2- Methane production

The landfill gas consists of many types of gases, the methane is considers the most valuable gas because it can be use as a source of energy. So the highest methane percent of the landfill gas the highest price reach. The relationships between daily and cumulative methane production per m^3 and the time per day are shown in Fig.(8). In general the methane production graph takes the same trend of landfill gas production because the amount of produced methane, m^3 depends on biogas production, m^3 and the percent of methane in biogas.

The cumulative methane production increases by increasing the time until reach the maximum value of 768,226 m^3 after 1860 day for the total area.

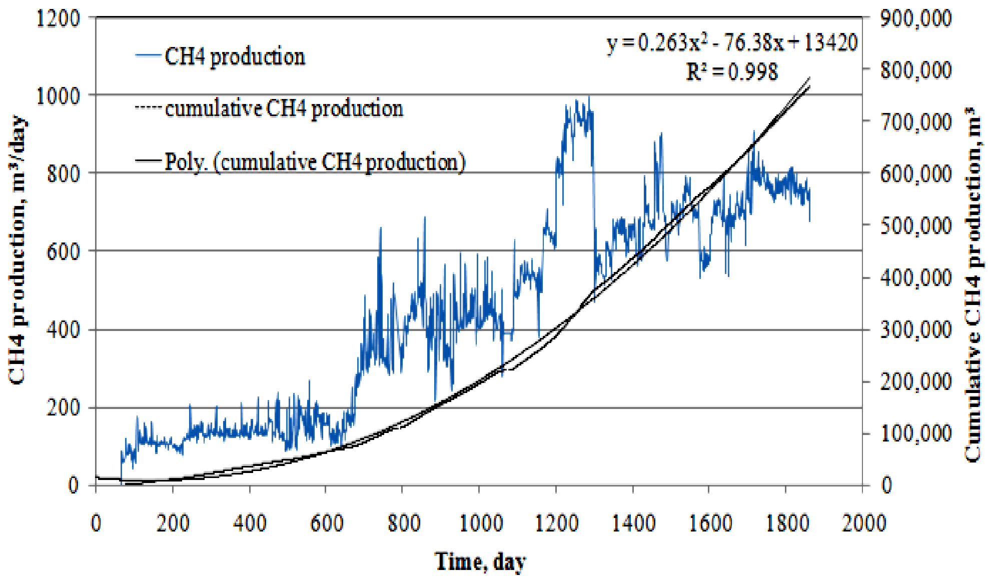

Fig. (8) : Daily and cumulative methane production.

It was observed that the highest methane production was 995.11 m^3/day after 1286 day, while the lowest methane production was 42 m^3/day in the beginning of landfill production. There are five stages of methane productions. The average daily methane productions were 121.45, 400.63, 515.92, 905.09 and 697.18 m^3 at the first, the second, the third, the fourth and the fifth stage respectively.
It was observed that the first stage is the lowest methane production because the aerobic bacteria consume oxygen and produce each of carbon dioxide and water. If the waste is highly compacted, however, methane production will begin earlier as the aerobic bacteria are replaced by methane-producing anaerobic bacteria. The fourth stage is the highest methane production because it is the highest gas production and methane percent.
A polynomial equation was determined to calculate cumulative methane production, m^3/day after any period of time, day as shown in Fig.(8).

3- Thermal energy production

The landfill produces large amount of gas, which is disposed by flaring system to destroy methane, compounds in the LFG such as volatile organic compounds and ammonia. This large amount of landfill gas isn't used in energy production, while gas can be used to generate electricity or to pump in to pipeline gas, which can solve many problems like controlling energy costs and reducing greenhouse gas emissions.
The relationship between daily and cumulative thermal energy production per kW.h and the time per day are shown in Fig.(9). In general the energy production graph takes the same trend of landfill gas production because the energy production depends on biogas production, m^3 and the percent of methane in biogas. It was observed that the highest daily energy production was 9951 kW.h after 1286 day, while the lowest daily energy production was 421 kW.h in the beginning of the production. There are five stages of energy productions. The average daily energy productions were 1214.59, 4006.35, 5159.19, 9050.9 and 6987.8 kW.h at the first, the second, the third, the fourth and the fifth stage respectively.
It was observed that the first stage is the lowest energy production because it is the lowest gas production, while the fourth stage is the highest energy production because it is the highest gas production stage.

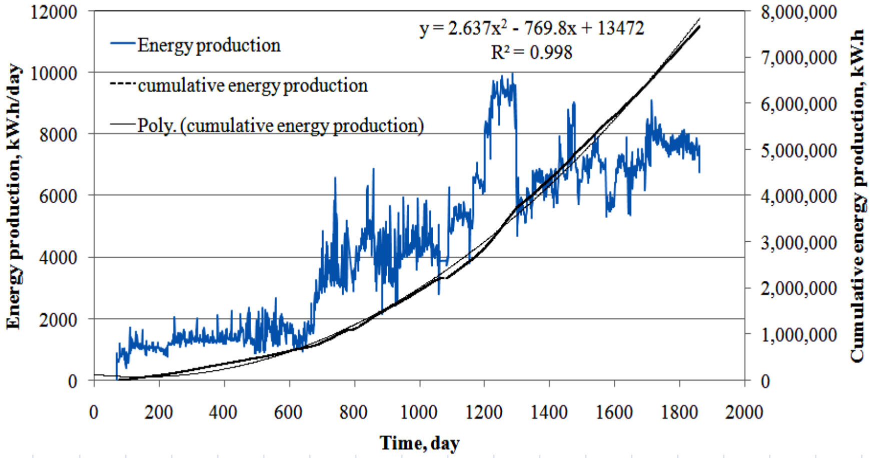

Fig. (9) : Daily and cumulative thermal energy production.

Table (4). Landfill gas production stages

Stage No	Time period, day	Average production				
		Biogas, m^3	CH4, %	CH4, m^3	O2, %	Energy, kW.h
1	680	429	30.5	121.45	9.5	1214.59
2	324	907	44.23	400.63	7.4	4006.35
3	197	1366	37.74	515.92	9.2	5159.19
4	97	2389	37.87	905.09	9.87	9050.9
5	563	1632	42.93	697.18	6.1	6987.8

An electrical efficiency of 35% can be used to calculate the amount of generated electricity from thermal energy according to (Surroop et al. 2011). The cumulative thermal energy production increases by increasing the time until reach the maximum value of 7665.2 M.W.h after 1860 day, which can transfer to 2682.82 M.W.h of electric energy.

Operating landfill consume about 219 M.W.h of electric energy through 1860 day in management and operating lighting system, computer, blower, pumps and flare system. This energy is generated by 11 kW diesel engine which consumes about 17,520 liter/year. The CO_2 emission from diesel fuel is about 43800 kg/year, so it is better to obtain the required electric energy in landfill operation from landfill gas instead of the diesel engine; this will also reduce greenhouse gas emissions and decrease fuel costs.

3-1 Landfill gas utilization systems

Biogas can be used in the production of heat and power, injection into the gas grid and as a transport fuel. The biogas must be treated before use to achieve the gas standards of each application.

The most common biogas conversion technologies are outlined below.

3-1-1 Combustion of biogas to generate heat

Biogas has a calorific value between 21-23 MJ/$m^3$and can be burned directly in a boiler to generate hot water or steam. This is a simple system, and reason for this solution not being the most used must be the fact that the price per kW power produced is almost higher than the price per kW heat. The heat can be exported but the cost of the infrastructure to transport the heat may be many times that of the boiler itself.

The heat from some boiler systems is used in greenhouses, either by normal circulation of hot water, or by heating of air that is blown into the greenhouses. This is also a relatively simple and efficient way to use the gas (Willumsen, 2001).

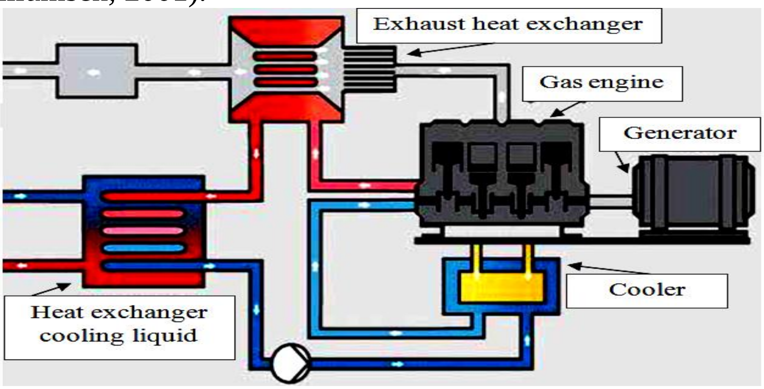

Fig. (10) : components of combined heat and power system.

3-1-2 Combined heat and power system (CHP).

Combined heat and power (CHP) is the conversion of the biogas fuel into heat and electricity. CHP plants are the most efficient system for utilizing the energy from landfills. The overall efficiency of CHP is around 85%, which is divided in to 35% electric energy and 50% heat energy (Willumsen, 2001). The CHP unit in a landfill gas plant usually consists of a reciprocating gas engine powers a generator that produces electricity. During operation, the reciprocating engine warms up, producing heat which is recovered by the oil cooling system, and emits large amounts of heat to the atmosphere in the form of exhaust gases. In CHP system, both types of heat are recovered by a heat exchanger system as shown in Fig.(10). The heat energy from the generator is available in engine jacket cooling water, engine lubrication oil cooling, First stage air intake intercooler, engine exhaust gases and engine generator radiated heat. The first three heat sources are recoverable in the form of hot water at temperature of 70-90˚C, while the engine exhaust gases typically leave the engine temperature between 400 and 500˚C, which can be used directly for drying leachate in a heat boiler to generate steam or via an exhaust gas heat exchanger combining with the heat from the cooling circuits (Sarah, 2007). The heat from the second stage intercooler is also available for recovery as a lower grade heat. Alternatively new technologies are available for the conversion of heat to further electricity, such as the Organic Rankine Cycle Engine.

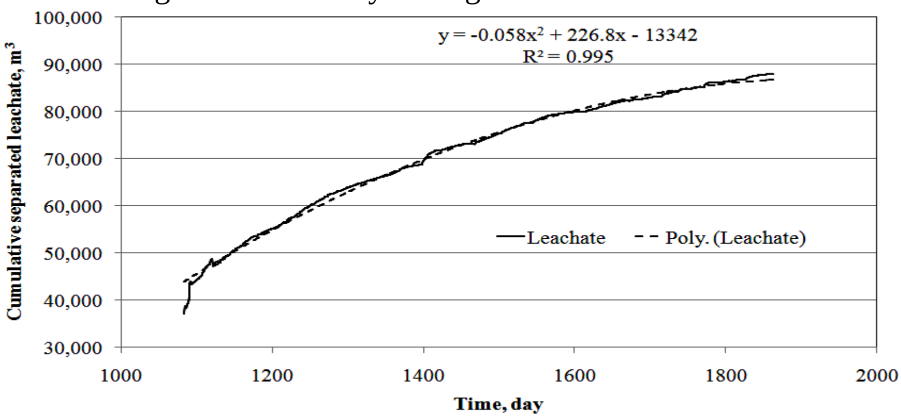

Fig. (11) : Cumulative landfill gas production.

4- Landfill leachate

The extracted leachate from the landfill was analyzed to evaluate the environmental impacts associated with solid waste landfilling. The results of physico-chemical analyses confirmed that the leachate characteristics were highly variable with sever contamination of organics, salts and heavy metals as presented in Tables (3 and 4). The leachate cannot be use in irrigation or in industry but it should be disposed by safe way to protect underground water and environment.

The presence of moisture (unsaturated conditions) in a landfill increases gas production because it encourages bacterial decomposition.

Moisture may also promote chemical reactions that produce gases at saturated conditions of the wastes so it is very important to extract leachate from the cells.

The relationship between the cumulative extracted leachate, m^3 and the time, day are shown in Fig.(10). In general the cumulative extracted leachate increases by increasing the time until reach the maximum value of 87,917.2 m^3 after 1860 day.

The extracted leachate from the landfilled waste is transported off site to the nearest wastewater treatment facility but this method cost a lot of money and need more efforts. So we can burn landfill gas in a boiler to evaporate leachate and generate hot water or steam. The evaporated steam was directed to a steam turbine to generate electricity. A polynomial equation was determined to calculate cumulative extracted leachate, m^3 after any period of time, day as shown in Fig.(10).

4. CONCLUSIONS

The cumulative values of gas production, methane production and energy production were increased by increasing the time until reach the maximum value of 1.93 million m^3, 768,226 m^3 and 7665.2 M.W.h respectively after 1860 day for the total cells area of 210,762m^2 and volume of 5.26 million m^3 respectively. The highest values of biogas production, methane production and energy production were 2598 m^3/day, 995.11 m^3/day and 9951 kW.h respectively after 1296 day, while the lowest values were 198m^3/day, 42 m^3/day and 421 kW.h respectively in the beginning of landfill production.

The cumulative electric energy production was 2682.82 M.W.h after 1860 day. The landfill consumes about 219 M.W.h of electric energy through 1860 day in management and operating landfill. The electric energy is generated by 11kW diesel engine which consumes about 17,520 liter/year. The CO2 emission from diesel fuel was about 43800 kg/year. A Combined heat and power system (CHP) is the most efficient system for converting produced landfill gas into 50% heat energy and 35% electric energy to reduce greenhouse gas emissions and decrease fuel costs.

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الملخص العربي

تقييم الطاقة الناتجة من المدفن الصحي بالحمام

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تعتبر إدارة النفايات الصلبة واحدة من أكبر المشاكل في جمهورية مصر العربية لأنها تؤثر على جميع جوانب حياة المواطنين و تقدر كمية النفايات الصلبة المتولدة في مصرحوالي٠.٣ – ٠.٨ كجم في اليوم للفرد. لقد زادت إجمالي النفايات الصلبة المتولدة سنويا في مصر حوالي ٣٦٪ منذ عام ٢٠٠٠ إلى ٢٠١٣ الي أن وصلت ٢٠.٥ مليون طن سنويا بالإضافة إلى ٦.٢ مليون طن من النفايات الصناعية تحتوي علي ٠.٢ مليون طن من النفايات الخطرة علاوة علي ٢٣ مليون طن / سنويا من المخلفات الزراعية. كما أن النفايات البلدية الصلبة تتكون من ٦٠٪ مادة عضوية و ١١٪ ورق و ٣٪ زجاج و ١٢٪ بلاستيك، ٢٪ منسوجات، و٢٪ معادن و ١٠٪ أخرى.

الجدير بالذكر أن مصر تعاني من نقص حاد في الطاقة مصر نظراً لتراجع إنتاج الطاقة بشكل مطرد منذ عام ٢٠٠٩ ويرجع ذلك إلى نقص في إنتاج الغاز الطبيعي و النفط وقد أدى هذا النقص إلى انقطاع الكهرباء المتكرر و من هذا المنطلق تم إجراء دراسة علي المدفن الصحي للمخلفات الصلبة في علم نايل بمنطقة الحمام و ذلك لتقييم أنتاجة من الطاقة عن طريق قياس معدل إنتاج الغاز الطبيعي و معدل إنتاج غاز الميثان و معدل إنتاج الطاقة الحرارية و معدل استهلاك الطاقة الكهربية ومعدل تدفق مياة الراشح و تقديم مقترح بالأستغلال الأمثل لهذة الغازات في أنتاج الطاقة. و قد تبين أن المدفن الصحي ينتج كمية هائلة من الغاز يتم التخلص منها بالحرق المباشر دون استخدامها في إنتاج الطاقة. يمكن إستخدام الغاز المنتج في توليد الكهرباء أو بضخة في خط أنابيب الغاز لخفض تكاليف الطاقة وتقليل انبعاثات الغازات المسببة للاحتباس الحراري. و بلغ إجمالي إنتاج الغاز الطبيعي، و إجمالي إنتاج غاز الميثان، و إجمالي إنتاج الطاقة الحرارية و إجمالي إنتاج الطاقة الكهربائية حوالي ١.٩٣ مليون متر مكعب و 768226 متر مكعب و 7665.2 ميجاوات و٢٦٨٢.٨٢ ميجاوات على التوالي بعد مرور ١٨٦٠ يوم من بداية الأنتاج . يستهلك المدفن الصحي حوالي ٤٣ ميجاوات ساعة من الطاقة الكهربية في السنة و التي يتم توليدهاعن طريق مولد ديزل ١١ كيلووات يستهلك حوالي ١٧٥٢٠ لتر ديزل في السنة، وتنتج انبعاثات ثاني أكسيد الكربون حوالي ٤٣٨٠٠ كجم في السنة. وأظهرت النتائج التي لا يمكن استخدام الراشح في الري أو في الصناعة ولكن يجب التخلص منها عن طريق آمن عن طريق تبخيرها و أستخدامها مع توربينات البخارية لتوليد الكهرباء.

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