A Review of Biogas Production Methods from Wastes and Sewage and the Process Explanation

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Background & Aims of the Study: Construction of biogas from plants, in addition to energy provision, could be an effective way to resolve the urban waste crisis and reduce emissions and bring about significant socioeconomic effects. In the present study, we have tried to investigate the role of bio-energy in providing energy supply, biogas production mechanism, the importance and benefits of biogas application, and to describe the process of organic matter decomposition with bacteria. This study has made use of library methods and database information from 1998 to 2014. Besides introducing different technologies for making use of biogas from landfills, its application, economic aspects in the world, and techniques of exploiting its resources have been also evaluated, and a model has been presented for determining the rate of biogas production based on grade A reaction kinetics.

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Background

Hygienic garbage dumping is one of the important and widely used techniques for managing solid waste landfills of urban and industrial areas. Garbage is one the factors affecting soil and water contamination, and dangerous leachate caused bv garbage accumulation is one of the most harmful contaminants of water and soil (1). One of the environmental out-turns of solid waste disposal in landfills is leachate production, mainly originated from the moisture content of dumped wastes and penetration of the liquid (caused by rainfall) into the landfill. Landfill leachate has a heterogeneous composition and is extremely

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pollutant each liter of which can contaminate 4000 liters of water (2). Environmental pollution, human and animal waste increase, and large amount of waste produced by millions of farm animals constantly boost environmental pollution which has caused problems for men; therefore, dealing with this problem is inevitable (3).

On the other hand, the population growth has increased the need for energy and fossil resources termination and shortage of energy threatens men. In recent years, the energy consumption augmentation has been the cause of a crisis in the world. Regarding the energy consumption from the limited supplies, which

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are mainly from fossil resources, the necessity of extensive research to look for other alternative energy-generating resources is obvious (4, 5). Therefore, global energy crisis and the increasing environmental pollution and emissions of greenhouse gases have made researchers to find means of making efficient uses of energy resources, i.e. to seek resources which satisfy energy needs and protect the environment. In this regard, researchers have triggered extensive investigations to find new and healthy resources. This attempt has led them to know and make use of new sources of energy such as wind, water, solar, biogas, and nuclear energies; among which biogas, as a renewable energy, has a particular value (6).

Aims of the study: The purpose of this study is to describe and evaluate how biogas is produced; various methods and mechanisms for biogas production in Iran and around the world are introduced. Application of biogas and the importance of using it as a renewable energy source are also investigated.

Materials & Methods

This study was conducted based on library facilities and database review such as SID, Magiran, and Sciencedirect databases from 1998 to 2014. For this purpose, biogas production, methane, landfill, and anaerobic fermentation terms were used both in Persian and English.

Results

A brief history of biogas

About 200 years ago, biogas phenomenon was discovered observing the flammable gases released from swamps and sewers, (7). Better identification of flammable gases was performed in 1630 by "Van Helmont"; 15 types of flammable gases were diagnosed; one of which is the gas that comes from perishable (rotten) or fermented food in intestines.

The beginning of investigation on anaerobic fermentation and its application in agriculture is related to a person called "Davy". In 1808, he produced 3.0 liters of methane (the most basic composition of biogas) through vacuum distillation of fermented cow manure (8). In 1859, the first anaerobic fermentation unit was constructed in Mumbai, India, and in 1860 the first sewage solids treatment plant was set up by a person called "H. Moras". In 1884, "Gayn," the student of Louis Pasteur, produced 100 liters of methane from the fermentation of a cubic meter of manure at 35 °C (9).

Development of biogas machines was held in abeyance during World War II in 1937. Because of the shortage of liquid fuels, the interest in producing methane gas continued after World War II. Generally, making use of biogas as it is popular today began after World War II. China, India, the Philippines, the Netherlands, Germany, and America are among the countries that have investigated and analyzed using biogas and the possibility of expanding and developing its application (7, 10).

In the late twentieth century, biogas was considered to be used in European countries. In 1988, more than 220 million tons of animal manure, 6 million tons of organic waste and 50 million tons of sewage sludge were processed through biogas machines. In Europe, some biogas units have been active for more than 20 years and more than 600 digester units are currently active there. Moreover, about 250 biogas units have been installed in Germany over the past five years (11).

In the recent decades, production and application of biogas has attracted specific attention because of energy shortage and rising prices of fuel in importing countries. In recent years, governments of India and China have commenced comprehensive attempts to produce

biogas to deal with the rapid increase of the imported oil price (4, 9).

The use of biogas in Iran dates back to three centuries ago. In fact, using biogas in Iran is attributed to the bath of Sheikh Bahaee (4, 7). Using cow dung, the first machine for methane production in Iran was constructed in 1975 in Niazabad village in Lorestan Province. In the years 1982 to 1986, New Energies Research Center located in Nuclear Energy Organization conducted particular studies in this field, including the construction of 10 biogas units in Sistan Baluchestan, Ilam, and Kurdistan Provinces. Besides, Mashhad and Shiraz biogas plants have been recently launched and hopefully in the near future will gradually contribute to increases in supplying urban energy needs (4).

Diagram of biogas energy consumption in different countries is shown in Figure 1. As it is seen, Sweden is the largest biogas consumer in the world and due to biogas production rather than petroleum; most of the produced biogas energy in Sweden is spent on transportation (9).



Figure 1: Diagram of biogas energy consumption in the world (9)

Properties of biogas

In fact, gas emitting from fermented animal, plant, and human waste in anaerobic conditions (the absence of oxygen) is called biogas. Biogas is also known as marsh gas and its main active • The biogas production methods and its process...

gas is methane (CH4). In addition to methane, biogas includes carbon dioxide (CO2), hydrogen sulfide (H2S), and other gases such as hydrogen (H2), oxygen (O2), and nitrogen (N2) (7,12). CO2 and contaminant concentration profiles can be used as a measure of biofilter performance (13). The composition of gases in biogas (4, 12) and their percentages are shown in Table 1.

Table 1: Constituent gases of biogas and their percentages

Material	Percentage
Methane (CH ₄)	55% to 65%
Carbon Dioxide	35% to 45%
(CO ₂)	
Hydrogen Sulfide	0% to 3%
(H_2S)	
Hydrogen (H ₂)	0% to 1%
Oxygen (O ₂)	0% to 1%
Nitrogen (N ₂)	0% to 1%

Biogas combustion temperature is about 700 °C and the flame temperature is 870 °C. Biogas, like other gases, is combustible and it ismixed with air at a ratio of 1 to 20 with high combustion speed. Its heating value is about 6 kWh $/m^3$ (i.e. equal to heating value of half a liter of diesel fuel).

The suitable pressure for cooking with biogas is between 5 and 20cm of water column (12). Heating value of 1 m^3 of biogas is equal to 0.4 liter of diesel, 0.6 liter of kerosene, 0.8 kg of coal, 1.46 kg of charcoal, 3.47 kg of firewood, and 0.43 kg of LPG (7).

Generally, garbage, rural and urban waste, and human and animal waste are biogas production resources. Figure 2 shows biogas production sources and their biogas production rate in terms of m^3/ton .

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Figure 2: Amount of biogas production from each source based on m3/ton

Biogas extraction technologies from urban solid waste landfill areas

The main purpose of the establishment of urban solid waste landfill areas and collection of their produced biogas is to prevent emissions of greenhouse gases such as methane and also to make use of the renewable energy in biogas. In this section, beyond introducing the general structure of modern urban landfill areas, different techniques of collecting landfill biogas (from urban solid waste landfill areas) are also examined and the factors affecting the implementation these techniques of are described.

The general structure of modern landfills

Waste disposal in landfills is generally done in two ways:

- 1. Ditch digging method
- 2. Surface disposal method

In ditch digging method, garbage is buried daily in ditches which are fitted according to the daily waste volume. These ditches typically have dimensions of about 100 to 400 ft length, 3 to 6 ft depth and 15 to 25 ft width. This method is mostly used in planar or non-planar sites with low slope and little groundwater (14).

In the surface disposal method, garbage is placed on a flat surface so that the waste is layered in less than 2 ft thick layers and packed Rajati H, et al./ Arch Hyg Sci 2014;3(3):140-151

before being spread to the next layer. This method is mostly used in areas with abundant canyons and valleys. Furthermore, if the location of landfill is full of low groundwater, using ditch digging method is impossible and the second method must be applied (14).

Different techniques for landfill gas collection

Landfill gas collection systems can be divided into two categories (15):

- 1. Active collection systems
- 2. Passive collection systems

Active collection systems use mechanical blowers or compressors to create the pressure gradient for extracting the landfill gas, while in passive collection systems normal pressure gradient developed between the landfill gas pressure and ambient air pressure causes gas transmission and extraction. Based on theoretical predictions. active collection systems have the most efficient performance in a variety of landfill gas collection systems. As stated, passive collection systems use natural gas pressure for extracting and collecting gas, while in active collection systems, a mandatory pressure gradient is used as the transmission force. However, studies have shown that if a suitable artificial landfill coating is used on the floor, walls, and on the upper surface to trap the landfill gas, a passive collection system can also develop an output similar to that of active systems (15).

Considering piping structure, active collection systems are divided into two groups: vertical wells and horizontal trenches. Selecting the type of gas collection system for a specific landfill depends on the existing specifications and limitations. Active gas collection systems with vertical well structure are usually recommended for landfills filled with the cell method. Cell method is a system that is designed for daily disposals and is sealed at the end of the day. The density of the compacted

waste in these cells is between 300 to 900 kg/m³ (4).

The common consequence of using this system is its low cost in comparison with the horizontal channel structure method. However, its installation is difficult, and due to the risk of falling of its heavy equipment down into the landfill, working on it is dangerous (15). Figure 3 shows an active collection system.



Active Landfill Gas Collection



Figure 3: Active landfill gas collection system Biogas production

Generally, biogas machines include two inlet and outlet ponds, a fermentation tank (digester), and a gas reservoir. Different conditions such as climate, technology, and economics have created various structures and models for biogas machines. In all these machines, water • The biogas production methods and its process...

and other raw materials are mixed in the inlet pond and then conducted to fermentation tank to be fermented and to produce gas and finally conducted toward the outlet pipe and outlet pond.

Embedding mixer for mixing the raw material for such an operation is a process which has recently become common in biogas machines for improving and speeding the fermentation process of releasing gas. Piping (including gas valve, connectors, and manometer), along with biogas purification equipment, is considered as one of the numerous supplements to biogas machines (16).

Different machines have been manufactured and operated in the world for the production of biogas. In this article, two systems with higher popularity are introduced. It should be noted that operational methods of other machines are similar to these (12, 17):

- 1. Biogas system with a floating lid which is known as Indian model.
- 2. Biogas system with a permanent and shared reservoir which is known as Chinese model.

1. Biogas system with a floating lid (Indian model)

This machine has been popular in India and thousands of devices of this kind are producing biogas in India. After being mixed with water, raw materials are conducted from inlet pond to the fermentation tank which is located in the ground.

Then, after gas production, fermented material moves toward the outlet pond and the produced gas is collected in the metal enclosure which is inversely located on the opening of fermentation tank (12, 17). Figure 4 is an overview of the device.

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Figure 4: Biogas system with a floating lid (Indian model)

Different parts of the device include: inlet pond, outlet pond, fermentation tank, and the gas chamber, each device description is given below:

• Inlet pond

As it is shown in Figure 4, this pond is built above the ground, and the outlet pond is laid on the other side of the fermentation tank and leads the mixture of water and raw material to the lower part of the tank. The basic task of this pond is to mix water and raw material manually. The moderate size of the pond with a cylindrical form has a radius of 40cm and maximum height of 40cm placed at a height above the ground level (12).

• Outlet pond

This pond is built opposite to the inlet pond and located above the ground, principle of transmission of fluid-pressure contributing to it, conducts the fermented material from the bottom of the tank to the outlet pipe and pond, . Outlet pipe is located 20cm above the ground and the inlet pipe is located at 50cm depth in the ground to discharge the fermented material from the outlet pipe after the entrance of the raw material (12).

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which is known Fermentation tank. as fermentation container or digester, is the most important part of a biogas system. Anaerobic fermentation is done in this tank by methane producing bacteria after the entrance of raw material; through stabilizing the temperature and moisture and preventing the influence of air, gas is produced in this tank. On average, about 150 L/m^3 of biogas is produced from the effective volume of the digestion tank (12). Inlet and outlet pipes inside the tank should be designed and installed in a way to transfer the fermented material from the bottom to the top of the tank and into the outlet pond after the entrance of new materials. In some cases, a mixer which has a critical role in gas production is also installed inside the tank (9, 12).

• Gas chamber

This container which is the place for accumulation of the produced gas from the fermentation of materials is a bottom-closed cylinder that is made of steel sheets of 1 to 3mm thickness. The lid of the chamber is made conical to accumulate more gas and also avoid rain water accumulation and corrosion. A pipe is welded to the top of the chamber to control its movement while consuming and producing gas. Thus, when more gas is produced, the chamber moves upward. A valve is also put on the lid to discharge the gas and conduct it toward the consumption chamber. Gas chamber must be de-rusted and painted to avoid and control internal and external corrosion (9, 12).

Advantages and disadvantages of biogas generator machines:

Advantages: learning its function is not difficult. Its removable lid causes constant pressure which is dependent on the weight of the lid (approximately 7 to 15cm of water). The volume of the stored gas is directly visible and fewer errors occur in its structure (18).

Fermentation tank

Disadvantages: the construction cost of a floating tank is high. Rusting steel parts shorten the life of the unit (15 years and 5 years in tropical climates). The lids cause heat dissipation. Painting costs paid for maintenance are high (18).

2. Biogas system with gas lid, a shared fermentation tank, and constant volume (Chinese model)

Since Chinese are the first inventors of this device, it is known as the Chinese model. This model is deviced like a dome tank and placed at the depth of the ground. Gas and fermentation share a tank, and the machine is located deep in the ground to save, the place, stabilize the temperature, and enhance its resistance in cold climates, eventually improving the device performance. The main design of the device is shown in Figure 5 (17).



Figure 5: Biogas machine with constant volume (Chinese model)

In the Chinese model of biogas production machines, gas and fermentation tanks are connected to each other and have made a particular reservoir. The gas tank has been made in a dome shape with brick or concrete coating. An outlet is embedded in the tank and functions like the previous machine. However, the produced gas moves upward and its pressure conduct it toward the consumption • The biogas production methods and its process...

section and pushes the fermented material toward the discharge chamber. Movement of the material toward the outlet pond regulates the pressure of the gas inside the dome. The more the pressure, the more material exits and if the internal pressure decreases, the material returns to the fermentation tank to compensate the pressure loss. As stated before, a crater (diameter of about 50cm) is embedded at the top of the gas tank. A concrete valve must be built into the crater and an opening should be considered for the passage of gas. After constructing the machine, the valve must be sealed to prevent gas leakage. The only difference between this machine and the Indian machine is the fixed size of the gas tank volume and no steel and spring application in its structure. In spite of engineering calculations required for the design, its establishment is not so challenging and complicated, encouraging the villagers to use it (12, 17).

Advantages and disadvantages of this type of biogas production machine (Chinese model): Advantages: the construction cost is low. Component units are not moving parts, so they will not rust and will last for a long time (over 20 years). It has underground facilities that are protected from cold winters and the space is saved. Native workers can be employed and its construction does not require proficient constructors (18).

Disadvantages: gas from the units cannot often be completely inhibited (permeability and cracking); the gas pressure is often very high and changes considerably. Digester temperature is low and does not function desirably in cold areas. It needs proper management (under the supervision of trained personnel) to achieve high efficiency (18).

Different aspects of biogas machines (Indian and Chinese models) have been compared in Table 2.

	Chinese Model (fixed lid)	Indian Model (floating lid)
Structure	It has an integrated construction and the problem	It has a simple structure but needs metal equipment.
	is the vault covering and impenetrability of water	(Metal lid)
	and gas.	
Input	Materials are generally a mixture of plant, animal,	It generally uses cows' waste.
material	and human waste.	
Output	The output material is discharged by a pump or	Output material discharge automatically.
material	bucket.	
Gas collection	There is no need for a separate cover and the	In floating lids, the height of gas tank is the indicator
	amount of gas is determined through the gas	of the amount of gas.
	pressure and the material off-going from outlet	
	pond.	
Gas pressure	Gas pressure is very high (Maximum1000 mm	Gas pressure is low (70 to 150 mm water column).
	water column).	
Cost	It is not costly.	Its cost is almost high because of metal equipment
		such as gas lid.
Appearance	Most of the machine is deep in the soil, so the	Most of the machine is visible and the surrounding
	system is completely clean and hygienic.	sanitation is poor.

Table 2: Comparison of Chinese and Indian biogas machines

Biogas production processes

Fermentation in biogas machine:

Waste and animal manure, that contain protein, cellulose, starch, sugar, carbon hydrates, and fatty acids, can convert into carbohydrates by enzymatic hydrolysis. Assisted by asidogenic microorganisms, these carbohydrates convert to organic acids and in a methanogenic fermentation process with methane-producing bacteria convert to methane, carbon dioxide, and other gases such as nitrogen, hydrogen sulfide, hydrogen, and carbon monoxide. Stages of this process are complex and are not performed easily. Some microorganisms go on different processes to turn cellulose to methane. Principles of digestion in the fermentation tank consist of two main stages each of which is done by certain bacteria. In fact, biogas is produced by bacteria which break down organic materials in anaerobic conditions. Thus, such a process is called anaerobic digestion which consists of two main stages. In the first stage, organic acids and in the second stage, methane gas are produced (12).

The first stage

Organic materials decompose by acid making bacteria that grow rapidly and decompose organic materials and convert them to acetic (CH3COOH) and propionic (C3H8COOH) acids, and later ammonia (NH3) and carbon dioxide (CO2) develop (12). Although heavy molecules of cellulose, protein, and fat change to smaller molecules like hydrogen, carbon dioxide, fatty acids, and amino acids by aquatic bacteria before the entrance of acid making bacteria to the cycle, these substances convert to acetate and hydrogen by acetate bacteria (18).

The second stage

In this stage, methane-producing bacteria break down fatty acids and their decomposition breaks down methane and carbon dioxide. These bacteria grow slowly and are very sensitive to the environmental conditions. Therefore, the activity of both bacteria (acid and methane producing bacteria) must be controlled, this is because if the activity of acid producers increases, PH of the solution declines

and the activity of methane producing bacteria and therefore the fermentation stopps (12).

The most important microorganisms that have a role in the fermentation process of biogas are:

- 1. Psychrophilic microorganisms
- 2. Mesophilic microorganisms
- 3. Thermophilic microorganisms

Mesophilics become activated at 30 to 40°C continue development. and their and thermophilics (heat-loving) become activated at temperatures of more than 50°C, so produce more gas, but due to their activity at high temperature, they are not affordable and the fermentation process of mesophilics has greater efficiency. Moreover, mesophilics energy cannot work in acidic state, and for the continuation of digestion, organic acids levels need to be controlled (12). Activity of bacteria is shown in Figure 6.

Environmental conditions of biogas system Anaerobic bacteria need a lot of time for sludge fermentation, changing it to methane gas, and adapting themselves to environmental changes. The main problem with methane production is to meet the required environmental conditions for bacterial growth and keep their population high to the desirable level for methane production. Environmental factors include:

Temperature

Temperature system efficiency, increases produces and reduces more methane, fermentation or reactor volume. Two heat limitations are known for the fermentation machine: one in mesophilic range, 20 to 45 °C and the other in thermophilic range, 50 to 65 °C . As thermophilic conditions require high temperature, consuming thermal energy may require high cost and therefore it is not very reasonable (19).

The best temperature for the system is about 35 °C which is difficult to maintain without a supplemental heating system. In fact, due to the aggravation of the fermentation process, the biogas production rate is low in temperatures above 40 °C. If the temperature reduces to 35 to 25 °C, the amount of produced gas drops about 25%. In temperatures above 60°C, the amount of produced gas reduces rapidly (8, 19).

PH

Methane-producing microorganisms are very sensitive to the environment PH. The best range for PH for biogas production is between 7 and 7.2. If PH reduces to lower than 6.6, it will have a significant negative impact on methane production and PH of less than 6.2 is very toxic and dangerous for methane bacteria (6, 8).

Ratio of carbon to nitrogen

Anaerobic bacteria need carbon and nitrogen to survive and carry out their activities. These bacteria usually use carbon as an energy source for their growth and building their cell wall. The ratio of these substances is critical for controlling interactions.

Carbon represents hydrocarbons, and nitrogen represents nitrate proteins and ammonia. The carbon to nitrogen ratio in initial organic composition of materials is effective on the methane percentage. The richer the raw material in protein, the earlier gas production starts and the more gas is obtained. Normally, the ideal C:N ratio required by bacteria is 25 to 30 (8, 20). When this ratio increases, nitrogen is finished earlier than carbon and the remaining carbon acidifies the environment. On the other hand, when this ratio decreases, nitrogen leaves the environment as ammonia gas and causes an alkaline state, and the gas production stops due to the lack of carbon (20).

Mixture retention time in the digester tank

This duration is the interval time between the entrance of a specific volume of manure to the digester tank through the inlet pipe and its exit

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through the outlet pipe. Retention time is very important because if the input material is not sufficient in the reservoir and the process of digestion and fermentation is not completed, the biogas is not going to be produced; when the digester tank is occupied with a specific volume of manure for only a short period, the aforementioned factor will not play a role in the digester tank designation. With increase in retention time, gas production has an increasing trend, i.e. methane production will increase with longer retention time (8, 19 and 20).

Solids concentration

Organic materials need to become diluted to be able to be absorbed by bacteria. The best concentration of materials for anaerobic fermentation process in biogas tanks is about 7 to 9% of solids. Increasing the concentration of materials causes adhesion and inhibits the reducing bacterial growth, and the concentration would result in a layered solution that requires constant stirring. Raw materials used in anaerobic fermentation have a high concentration and need to be diluted with a certain proportion of water. It must be noted that both dilution and concentration of materials decelerate the fermentation process (20).

Particle size

Particle size is influential on the reaction and fermentation rate of materials. The smaller the particle size, the more the contact area, and therefore gas production increases (20).

Biogas production model based on reaction kinetics

Here, a simple model is presented for the prediction of biogas production in the biogas tank with continuous and discontinuous circulation based on the rate of decomposition reaction (K). Using this model in the following simple equations, the rate of biogas production (y (t)) at the time of (t) can be predicted. Assuming that the reaction rate is grade A, for Batch Reactors (2):

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Equation (1): $C = C_0 (e^{-Kt})$

In this equation, C_0 is the initial concentration of substrate and C is the concentration of the substrate after time t. Figure 7 shows the correlation between substrate concentration and biogas production rate at time t. y_m indicates the rate of biogas production in the infinite time (2).



Figure 7: Correlation between biogas production rate changes and substrate concentration

Thus, the relationship between the deleted substrate and the produced biogas can be written as (2):

Equation (2): $(C_0 - C)/C_0 = y_t/y_m$

Subtracting two sides of equation (1) from C_0 , we will have (2):

Equation (3): $C - C_0 = C_0(e^{-Kt} - 1)$

Consequently:

Equation (4): $(C_0 - C)/C_0 = 1 - e^{-Kt}$

Thus, applying equations (2) and (4) we will have:

Equation (5): $y_t = y_m (1 - e^{-Kt})$

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Discussion

Emission of carbon dioxide and methane, that increases greenhouse gases and environmental pollution, is one of the most important effects of unsanitary landfill waste. Thousands of tons of human and plants waste in villages and urban areas that threaten human and environmental health and increases greenhouse gases remarks the necessity of using biogas technology more than before. Putting under control the produced gas and its extraction not only reduces the environmental problems, but also can be used as a renewable source of energy. This paper describes the methods through which biogas is produced by microorganisms and anaerobic bacteria. Besides, biogas production and consumption requirements are explored.

In fact. besides reducing environmental pollution and greenhouse gases, biogas production can manage gases formed by anaerobic reactions of organic substances in waste materials. Moreover, electrical energy can also be produced as an alternative for fossil fuels such as oil and coal. The biogas can be directly used or as combustion fuel connected to the electricity generator or as heat and power production resource or as an improvement and promotion of the vehicle fuel consumption quality, or injected into a city gas network.

Finally, a model is presented for biogas production rate in terms of substrate concentration based on grade A reaction kinetics. Applying this model, the rate of biogas production (y (t)) in the time of (t) can be predicted via simple equations.

Reviewing several articles on biogas production in Iran and salient countries in this field can be considered as the strength of the study. Examining sixteen years old resources allowed the researcher to obtain complete data on biogas production method. Due to the limited

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number of biogas plants in Iran, a few articles and quantitative studies have been written and conducted in this field. For further research, the followings are offered:

- 1. In order to apply different technologies for biogas energy consumption in Iran, urban waste landfills in large provinces of the country should be examined technically and reasonable technologies in each province determined according to regional circumstances.
- 2. To review all the existing technologies in areas where landfill biogas energy is consumed, economic analysis should be done according to local conditions. In this regard, the establishment of a piloting program to assess different technical-economic plans for using biogas energy in the country is suggested.
- 3. Considering the availability of urban waste as a source of biogas energy production, it is recommended to use this energy in remote villages which are deprived of electricity and natural gas, or to even consume it directly.

Footnotes

Conflict of Interest:

The authors declared no conflict of interest.

References

- Kheradmand S, Karimi Jashni A, Monajemi P. Anaerobic Treatment of Landfill Leachate: A Case Study of Shiraz Landfill Leachate. J.Water & Sewerage 2009; 4: 82-90. (in Persian)
- Shokuh A, Safari E, Hashemi S.H, Ebadi T. Comparison Between Anaerobic Treatments of Leachate Exist in Municipal Landfill Containing Total and Solution Substrate. Sci & Tech of Env J. 2007; 11(1): 31-38. (in Persian)
- 3. Ahmadpur A, Abbaspur D, Javidfar M.R. Investigation of Biogas Generation and Application

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with Regard to Safety. O&E J. 2011; 5: 4-14. (in Persian)

- Yazdandad H, Karimi A, Fatehi I. Using Energy of Mashhad Biogas Powerhouse Plant in order to Protect the Environment J. 2011; Available at: http://www.civilica.com/Paper-ETEC01-ETEC01_187.html
- Amini Borujeni H.R. Biogas, Requirement or Obligation. Standard & Iranian Goods 1998; 76: 2-6. (Persian)
- Wikan Widodo T, Asari A, Ana N, Elita R. Design and Development of Bigas Reactor for Farmer Group Scale. Ind Agric Sci J. 2009; 2(2): 121-128.
- Vafabakhsh K. Biogas, Energy Recovery from Organic Wastes. Sci Info. 2001; 15(12): 22-24. (in Persian)
- 8. Perea KUC. Investigation of operating conditions for optimum biogas production in plug flow type reactor. KTH School of Industrial Engineering and Management: KTH Ind. Eng & Manag; 2011.
- 9. Hoseinzade MM, Afshar R. Renewable biogas energy. Roshd (Geology) 2009;14(9):49-52. (in Persian)
- Markowski M, Białobrzewski I, Zieliński M, Dębowski M, Krzemieniewski M. Optimizing lowtemperature biogas production from biomass by anaerobic digestion. Renewable Energy 2014; 69: 219–225.
- 11. Shah Mohammadi M. Bright prospects for biogas; Available at: http://ch4.blogfa.com/ post-3.aspx

- Amini Borujeni H.R. Characteristics and methods of biogas production. Standard & Iranian Goods 1998; 78: 42-47. (in Persian)
- Ardjmand M, Safekordi A, Farjadfard S. Simulation of biofilter used for removal of air contaminants (ethanol). International Journal of Environmental Science & Technology. 2005; 2(1):69-82.
- Sufestaei A, Karimi F. Technologies for extracting biogas from municipal landfill. Air Cond. 2009; 19: 64-69. (Persian)
- Ranson D. Landfill Gas Management Facilities Design Guidelines. 1th ed. Columbia: M.o.E; 2010: 56-59.
- Ta'ati A.M. Biogas Production from Rural Waste. H & R Envir J. 2000; 90: 64-69. (in Persian)
- Hejri Z, Sahebjami N. Investigation of biogas production from wastewater and garbage. 1st Conf of Bioenergy: Tehran, Iran, October 2010.
- Ghardashi A, Adl M. Biogas in Iran: Existence Potential, current Extraction and future outlook. 3rd Conf of Energy: Tehran, Iran, May 2001.
- Zhao Ch. Effect of Temperature on Biogas Production in Anaerobic Treatment of Domestic Wastewater UASB System in Hammarby Sjöstadsverk. 2011: 8-10.
- Rahi A, Garshasbi M. Biogas generation process and manufacture of biogas plant in order to electricity generation.1st Conf of Bioenergy: Tehran, Iran, October 2010.