Global NEST Journal, Vol 17, No 3, pp 487-497, 2015

PREDICTION OF GAS EMISSION AND DERIVED ELECTRICAL POWER GENERATION FROM SHIRAZ LANDFILL

FARZADKIA M.[1]
DJAHED B.[2,*]
SHAHSAVANI S.[3]
DEHGHANIFARD E.[4]

[1]*Department of Environmental Health Engineering, School of Public Health*
Iran University of Medical Sciences, Tehran, Iran
[2]*Department of Environmental Health Engineering*
Iranshahr University of Medical Sciences, Iranshahr, Iran
[3]*Department of Environmental Health Engineering, School of Public Health*
Shiraz University of Medical Sciences, Shiraz, Iran
[4]*Department of Environmental Health Engineering, School of Public Health*
Alborz University of Medical Sciences, Karaj, Iran

Received: 05/01/2014
Accepted: 12/05/2015
Available online: 24/06/2015

*to whom all correspondence should be addressed:
e-mail: Babak.Djahed@gmail.com

ABSTRACT

Landfilling has been considered as the most common method for solid waste disposal in developing countries which is faced with several issues, such as gas emission. Methane as a greenhouse gas is the main landfill gas which could be applied as a fuel for electrical power plants. In this study, the gas emission of Shiraz landfill site was predicted by using USEPA model, for this purpose, after determination of the solid waste physical composition on Shiraz landfill site, the L_0 and k constants were estimated by Monte Carlo method, as well as the rate of gas collection and the rate of electrical power generation capacity were estimated under existing and ideal scenarios. The results showed that gas production would reach its peak up to 5.7×10^7 m^3 $year^{-1}$ by 2039. The maximum electrical power generation was also similar to the pattern of gas production in the landfill and would be 2545GWh and 4019GWh for the existing and ideal conditions, respectively in 2039. Results showed that the recovery of biogas at Shiraz landfill could be a desirable alternative in different available waste management options for this city.

Keywords: Solid waste, Landfill, Greenhouse gas, Electrical power, Shiraz

1. Introduction

Nowadays, generation of solid waste has been increased due to the socio-economical developments in the developed countries and increase of population in the developing countries (Czepiel *et al.*, 2003; Park and Shin, 2001), hence this situation causes an increasing environmental concern about disposal of municipal solid waste in all over the world (Salehi *et al.*, 2011). Landfilling is one of the most common methods for disposal of the municipal solid wastes which avoids separation, recovery, and incineration processes from these valuable materials (Desideri, 2003, Park and Shin, 2001). It is estimated that about 1.5 billion tons of the produced solid wastes in the world are annually buried in landfills (Themelis and Ulloa 2007). However, Landfilling usually leads to secondary pollutions, such as surface and ground water contamination by leachate, and also causes air pollution by emitting unpleasant odors produced from decomposition of organic materials (Park and Shin, 2001; Tsatsarelis and Karagiannidis, 2009; Zamorano *et al.,* 2007). During the biological processing in degradation of organic wastes, methane, carbon dioxide, and other trace gases could be emitted from landfills and gas generation may be continued up to 30-100 years (Faour *et al.*, 2007; Zamorano *et al.*, 2007). One of the main components of landfill gas (LFG) is methane (40-70%) (Bicheldey and Latushkina 2010; Ozcan *et al.* 2007). Due to the molecular structure and stability of methane in the atmosphere (about 9 years), the global warming effect of this gas is about 20-25 times more than carbon dioxide (Ozcan *et al.* 2007; Park and Shin, 2001; Zamorano *et al.*, 2007). Studies showed that 3-19% of total global emissions of methane which was about 40Tg year^{-1} was produced in the landfills (Ozcan *et al.*, 2007, Park and Shin, 2001, Wang-Yao *et al.*, 2006, Zamorano *et al.*, 2007) and this amount comprises about 10-19% of anthropogenic methane emissions (Stern *et al.*, 2007). By using the methane gas in the landfills, we can reduce its greenhouse effects and also obtain a renewable source of energy (Machado *et al.*, 2009; Park and Shin, 2001, Wang-Yao *et al.*, 2006, Zamorano *et al.*, 2007). Based on the previous studies, about 83.56% (8666001.56 tons year^{-1}) of the produced solid wastes in Iran are disposed using the landfilling method (Nabizadeh *et al.*, 2008). This rate of buried solid wastes could lead to the production of large amounts of methane gas which is estimated to be about 0.3 million tons per year (Farzadkia *et al.*, 2011b); hence, it could be an enormous source of fuel for power plants and using this produced LFG in the power plants installed close to the landfill could be considered as the best option. Evaluation of methane generation in the landfills is the first step and the most important factor for construction of these types of power plants (Machado *et al.*, 2009). Therefore, the present study aims to evaluate methane gas generation in Shiraz landfill and predict the appropriate capacity of its electrical power plant.

1.1. Site specifications

Shiraz is the capital of Fars province which is located in south of Iran. In the last population census, the population of Shiraz was estimated about 1,200,000 individuals making it the sixth largest city of Iran. In 1997, 20 hectares of Shiraz public lands were allocated for Shiraz's solid waste landfilling. It is anticipated that this landfill will respond to all the city’s needs for 40 years. In this site, the rate of solid waste burial, which is performed daily and continuously through area-tranche method, is about 900 ton day^{-1}**.** The length, width, and depth of tranches in this landfill are about 800, 100, and 16 m, respectively. Besides, each layer of this landfill is 8m and after each layer, it is covered by 1m of soil. In order to collect the produced LFG from trenches, some perforated pipes were vertically planted inside the buried solid waste rows which were connected to a main pipe with the capacity of 840m^3 h^{-1} transferring the collected LFG to a 7.71MWh year^{-1} electrical power plant. The Geographical location of Shiraz landfill is depicted in Fig.1.

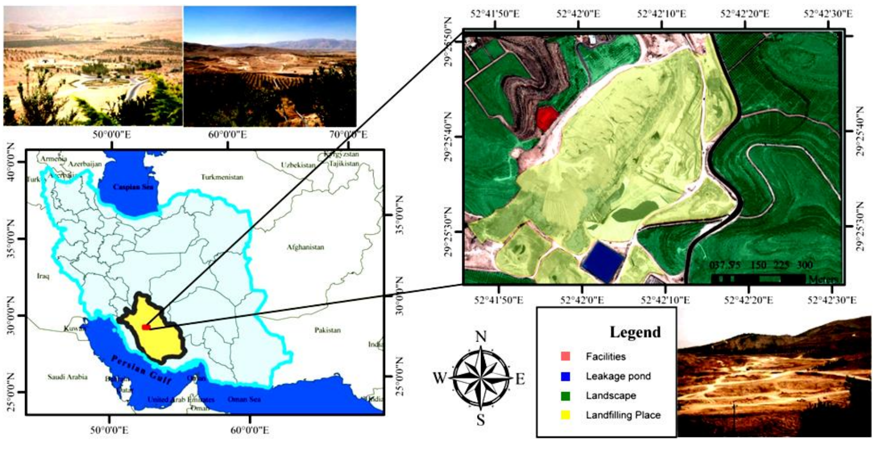

Figure 1. Geographical location of Shiraz Landfill

2. Materials and Methods

2.1 Solid waste physical composition

To achieve the exact and real physical composition of Shiraz municipal solid waste, we collected and analyzed 12 samples of solid wastes, which gathered at the landfill site during 4 periods (half of each season). By a hand-sorting procedure, the gravimetric composition of the waste was determined into 8 separate categories (food waste, paper and cardboard, textiles, yard waste, metals, glass, plastics, other materials). Also the water content of the gathered samples was determined using the wet-weight method. For this purpose approximately 0.5-1 kg waste sample was placed in an oven at 105 °C until a constant weight achieved.

2.2 Methane emission modeling

The rate of biogas production could be estimated by different methods, some of which are based on the equations which require the composition of solid waste. Besides, the experiences obtained from completely controlled environments are used in some methods. In some other models, on the other hand, the data obtained from field measurements are used (Bicheldey and Latushkina, 2010; Tsatsarelis and Karagiannidis, 2009; Wang-Yao *et al.*, 2006; Zamorano *et al.*, 2007). Some models for predicting the biogas production rate are illustrated in Table1.

Table 1. Some models for estimation of methane emission from landfills (Kamalan *et al.*, 2011, Thompson *et al.*, 2009; Farzadkia *et al.*, 2011b)

Name of model	Model	Comment
EPER Germany	M_e=M×BDC×BDC_f ×F×D×C	Zero Order
SWANA	Q= ML_0/t_0-t_1	Zero Order
IPCC	Q=(MSWT×MSWF×MCF×DOC×DOC_f ×F×(16/12) -R)×(1-OX)	Zero Order
SWANA	Q=ML_0 e^{-kt}	First Order
TNO	α_t=ς1.87A$C_0K_l e^{-k_l t}$	First Order
Land GEM*	$Q_{CH_4}=\sum_{i=1}^{n} k_{L_0} M_i (e^{-kt_i})$	First Order

*The equation used in the present study.

The first order decay model (Eq.1) is the most useful one which is recommended by IPCC and USEPA (IPCC 2006; US-EPA 2005a); therefore, this model was used in the present study in order to estimate the rate of biogas production of Shiraz landfill.

$$Q=\sum_{i=1}^{n} k_{L_0} M_i e^{-kt_i} \quad (1)$$

In this model, Q (m^3 $year^{-1}$) is annual methane generation in the year of calculation, k ($year^{-1}$) is methane generation rate constant, M_i (years) is weight of the accepted waste in the i^{th} year and L_0 (m^3 CH_4 Mg^{-1} of MSW) is potential methane generation capacity; the methods which used for estimation of k, L_0 and M_i, are explained in following.

2.2.1 Estimation of L_0

There are different models for estimation of L_0 (Machado *et al.*, 2009; Thompson *et al.*, 2009); according to the available information and by considering the results of the study which Farzadkia *et al.,* conducted on the estimation of methane production potential of waste buried in Iran (Farzadkia *et al.*, 2011b), the revised IPCC model (Eq.2) was used to determine L_0. In this model, L_0 (m^3 CH_4 Mg^{-1} of MSW) is determined through a mass balance approach that contains the determination of the degradable organic carbon content of the waste.

$$L_0=\frac{F_{CH_4}\times MCF\times \frac{16}{12}\times(\sum_{i=1}^{n} DOC_i \times DOC_{f_i} \times FR_i)}{\rho_{CH_4}(1+w)} \quad (2)$$

In Eq.2, the F_{CH4} is the percentage of the CH_4 volume concentration, MCF (unit less) is a correction factor, DOC_i (%) is the degradable organic carbon content in i^{th} constituent of solid waste, DOC_{fi} (%) is a portion of DOC_i that degraded and converted to the gaseous form and ultimately released from landfill, FR_i (%) is the portion of each component in the waste composition, ρ_{CH4} (kg m^{-3}) is the density of methane (0.717 kg m^{-3}) and w (%) is the water content of the waste. The parameters of DOC_i and DOC_f for different constituents of Shiraz solid waste are estimated using Table 2. Besides, The F_{CH4} was selected between 50-60%; the selection of this range was based on literatures and previous studies (Omrani *et al.*, 2008; Tchobanoglous *et al.*, 1993; Pichtel, 2005). The correction factor of MCF shows a portion of the waste which decomposes under aerobic condition prior switching of landfill to anaerobic condition, considering the high deep of the studied landfill, the value of this parameter was selected between 0.8-1 (Table 2). Also the coefficient of 16/12 in this model is molecular weight ratio of CH_4 and C.

Table 2. Correction factor for methane, fraction of degradable organic carbon and biodegradable carbon (Machado *et al.*, 2009; Farzadkia *et al.*, 2011b)

Correction factor for methane		Fraction of degradable organic carbon and biodegradable carbon		
Type of landfill site	*MCF*	Type of waste	DOC (%)	(%) DOC_f
Managed-anaerobic	1.0	Paper and paperboard	100	35
Managed-semi-aerobic	0.5	Food waste	100	75
Unmanaged-deep(>5m waste) and /or high water table	0.8	Yard waste	100	50
Unmanaged –shallow (<5m waste)	0.4	Textiles	50	30
Uncategorized landfill	0.6	-	-	-

2.2.2 Estimation of k

In determining the methane generation rate in the landfills, another important kinetic factor is the methane generation rate constant (k), in present study, the value of k was determined by considering Table 3 and Eq. 3.

$$k=\frac{\sum_{i=1}^{n} k_i \, FR_i}{\sum_{i=1}^{n} FR_i} \tag{3}$$

In Eq. 3, the k_i (unit less) is the methane generation rate constant for each fraction of solid waste and considering the dry and temperate climate of Shiraz city, the range of this parameter was selected from table 3. Also the FR_i (%) is the fraction of each component in the solid waste.

2.2.3 Estimation of M_i

One of the parameters in model 2 is the waste buried in the i^{th} year. The data on the rate of buried waste were available from 1997 to 2013, and Eq.4 was used in order to calculate the rate of waste buried until the end of landfill life in 2037.

$$P_i=P_0(1+\alpha)^i \tag{4}$$

In Eq.4, the P_i is Population in the i^{th} year, the P_0 is Population in the current year and α is Population growth rate. The rate of the population growth was selected as 1.5% and with respect to the solid waste minimization policy and due to good market exist in Iran for recycled materials (Farzadkia *et al.* 2011a), the rate of waste production per capita was considered as 700gr constantly in all years. The calculated population rate in the ith year was multiplied by the rate of waste production per capita (700 gr) to determine the waste buried in the ith year.

Table 3. The values of k recommended by IPCC 2006 (Machado *et al.*, 2009; Wangyao *et al.*, 2010)

Type of waste		**Dry boreal and temperate Climate**		**Wet boreal and temperate climate**		**Dry tropical climate**		**Wet tropical climate**	
		Default	**Range**	**Default**	**Range**	**Default**	**Range**	**Default**	**Range**
Slowly degrading waste	Paper/textiles waste	0.04	0.03–0.05	0.06	0.05–0.07	0.045	0.04–0.06	0.07	0.085-0.06
	Wood/straw waste	0.02	0.01-0.03	0.03	0.02-0.04	0.025	0.04-0.02	0.035	0.05-0.03
Moderately degrading waste	Other (non-food) organic putrescible/garden and park waste	0.05	0.06-0.04	0.1	0.1-0.06	0.065	0.08-0.05	0.17	0.2-0.15
Rapidly degrading waste	Food waste/sewage sludge	0.06	0.08-0.05	0.185	0.1-0.2	.0085	0.1-0.07	0.4	0.7-0.17
Bulk waste	-	0.05	0.06-0.04	0.09	0.1-0.08	0.065	0.08-0.05	0.17	0.2-0.15

2.3 Electrical power generation

In order to estimate the capacity of electrical power plant, two scenarios were defined for efficiency of the LFG collection system in Shiraz landfill. The first scenario estimated the efficiency of the LFG collection system in the existing condition of the landfill. In doing so, the efficiency rate of the collection system was calculated by using the Mexico Landfill Gas model version 2.0. In the second scenario (ideal scenario), the efficiency rate of the gas collection system was selected in accordance with the IPCC recommendation; based on these scenarios, the rate of gas collection was calculated in both the existing and ideal conditions. In comparison to natural gas with 37.25 MJ m^{-3}, LFG with 15-19 MJ m^{-3} energy content has a low heating value; therefore, by assuming 3.605 MJ KWh^{-1} for mechanical equivalent, if the overall system efficiency be 20%, the conversion rate will be 18.004 MJ KWh^{-1}. The electrical energy production was calculated through Eq.5 (Tchobanoglous *et al.*, 1993).

$$\text{Electrical energy production(KWh)} = \frac{\text{fuel Thermal energy(J)}}{\text{Heat exchange rate}\left(\frac{J}{KWh}\right)} \tag{4}$$

Finally, by assuming the use of 1MW generators, the appropriate capacity of electrical power plant was determined in ideal and existing conditions.

2.4. Uncertainty Analysis

The input value of parameters in model 2 and 3 are the field averages or they are estimates from previous studies that could be included a range of values, this situation shows that the expected coefficient of L_0 and k for this landfill could not be a deterministic value, and it is associated with uncertainty, hence in these cases the uncertainty analysis is essential. When uncertainties are large or probability distribution is non-Gaussian, the numerical statistical techniques like Monte Carlo are suitable for estimating uncertainty in emission factor (IPCC 2000). Monte Carlo simulation is a method that uses random numbers in input parameters to identify the stochastic behavior of the model and it shows the extreme possibilities along with all possible consequences. In present study @Model Risk software version 5.0.2.1 was used to perform the Monte Carlo simulation. For this simulation, the probability distribution of F_{CH4} was selected uniform and for K_i, MCF and DOC, the triangle distribution was utilized, also for W and FR_i parameters the normal distribution were selected. 50000 iterations were used to perform mentioned simulation.

3. Results and Discussion

The physical analysis of Shiraz solid waste indicated that the food waste is dominated fraction; also, as shown in Fig. 2, the categories of plastics and papers are the other major constituents. These results show that the organic fractions of Shiraz solid waste are high significantly. Also the average water content of gathered samples were determined as 65.8±12.3 percent.

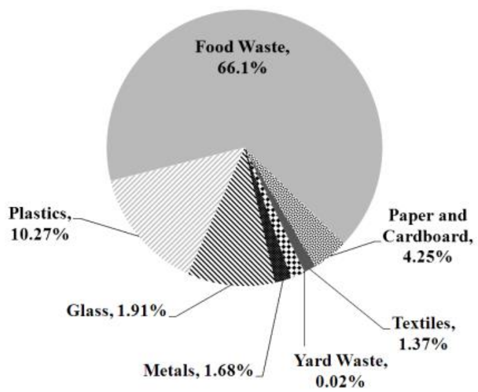

Figure 2. Physical composition of Shiraz solid waste (percent of mass)

In the LandGem model, values of L_0 and k are highly critical for determining the LFG generation (Zamorano *et al.*, 2007). The probability distribution of L_0 and k were determined by Monte Carlo simulation and the results are shown in Fig. 3 and 4. The effective parameters which influence the L_0 value are solid waste composition and the decomposable fraction of the organic material (Wang-Yao *et al.*, 2006). The recommended amounts for L_0 in different sources are less than 100 to 270 cubic meters per each ton of the buried solid waste (Faour *et al.*, 2007; Machado *et al.*, 2009, US-EPA 2005b; Wang-Yao *et al.*, 2006). Monte Carlo simulation showed that the minimum and maximum of L_0 in Shiraz landfill could be 57.25 and 304.75 m^3 ton^{-1} respectively, but as seen in Fig. 3 the most probable range of L_0 is around 150 m^3/Mg, hence the mean of obtain distribution (155.22±34.63) was considered as L_0. This measure is quite consistent with the results obtained in the studies conducted by Farzadkia *et al.* and Adl *et al.;* Farzadkia *et al.* reported 162.7m^3 LFG production per each ton of waste buried in Iran (Farzadkia *et al.* 2011b). In the other study on Shiraz municipal solid waste, Adl *et al.* calculated the rate of L_0 as about 143m^3 ton^{-1} (Adl *et al.*, 2005), which is close to the results obtained in the present study. The high L_0 obtained in this study is due to the high biodegradable fraction of solid waste buried in Shiraz landfill. For instance, Faour *et al.* (Faour *et al.*, 2007) conducted a study on three landfills in the U.S. and calculated lower L_0 in comparison to present study (115, 95 and 87m3 ton^{-1}). This difference might be due to the existence of lower organic materials in the U.S. municipal solid waste compared to Shiraz municipal waste.

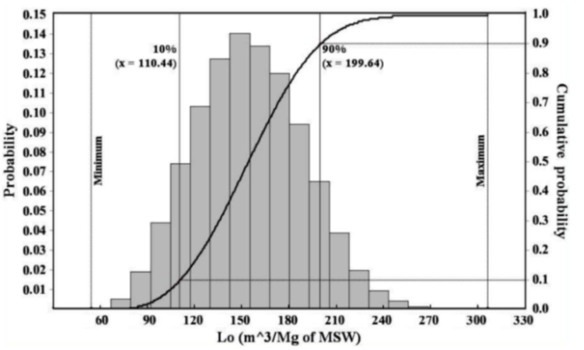

Figure 3. Probability distribution of L_0

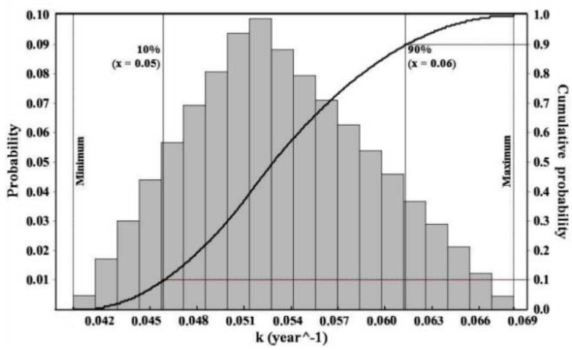

Figure 4. The probability distribution of k

Methane generation rate constant (k) is related to several factors, such as atmospheric precipitation, waste moisture content, pH, temperature, and nutrients availability for methane producing microorganisms (Faour *et al.*, 2007; Machado *et al.*, 2009; US-EPA 2005b; Wang-Yao *et al.*, 2006), and may range from 0.003 to 0.21 (US-EPA 2005b). As the rate of biodegradability, moisture of solid waste, and temperature of landfill site rises, the k constant rises, as well. For instance, Wang-Yao *et al.* conducted a study in Thailand and due to the high fraction of organic materials which could rapidly become degraded, the high moisture content of the waste buried in this area, and the wet tropical climate in Thailand, they decided to take a high k value (0.15) for LFG estimation. Based on United States Clean Air Act (CAA), k values of 0.05, 0.02, and 0.04 are recommended for sanitary landfills in arid regions and landfills having leachate recirculation. In the present study, the Monte Carlo simulation shows that the most probable range of k is approximately between 0.05 and 0.054 (Fig. 4); hence the mean of obtained distribution (0.053±0.0057) was used as value of k. This value is consistent with the k constant Omrani *et al.* (0.06) and Adl *et al.* (0.05) selected in their studies which were conducted on LFG production in Shiraz Landfill (Omrani *et al.*, 2008; Adl *et al.*, 2005).

In order to optimize the dimensions of a power plant fed by LFG, it is critical to quantify LFG production over several years. Therefore, biogas generation in Shiraz landfill was calculated by using the obtained L_0 and k as well as Eq.1. In general, biogas production models assume the landfills as batch reactors in which anaerobic reaction is hypothesized as first order (Manna *et al.*, 1999). Since the first order decay model applies the effect of age, it is most widely used for estimating the rate of LFG production (Mor *et al.*, 2006) and it was used successfully for predicting the rate of methane gas emission in landfills in many studies, such as Faour *et al.*, 2007; Machado *et al.*, 2009; Wang-Yao *et al.*, 2006; Zamorano *et al.*, 2007. Also, Di

Bella *et al.*, 2011, showed this model to have a good agreement with the field measurements. Hence, the first order model (LandGem) proposed by USEPA was used in the present study in order to estimate the rate of biogas production of Shiraz landfill. Fig.5 shows the estimation rate of methane, LFG, and carbon dioxide gas generation between 1997and 2136 by the first order decay model. As demonstrated, methane gas generation and LFG production will reach their maximum rates by 2039 (5.7×10^7 m^3 and 1.12×10^8 m^3, respectively). Omrani *et al.*, 2008, estimated the maximum methane generation (1.5×10^6 m^3 $year^{-1}$) to occur in Shiraz landfill in 2021. The lower methane generation and year of maximum methane generation in that study might be due to the researchers' lower L_0 calculation and higher k selection. From 1997 that Shiraz landfill was opened to 2137 that the production and emission of LFG will be finished, the rates of methane, carbon dioxide, and the total generated gases in this landfill will be 2.3, 2.4, and 4.8 billion cubic meters, respectively. Hence, if we have no gas collection systems and gas recycling programs, averagely 34 million ton methane and carbon dioxide will be emitted to atmosphere through all the years the landfill is generating biogas (1998-2137).

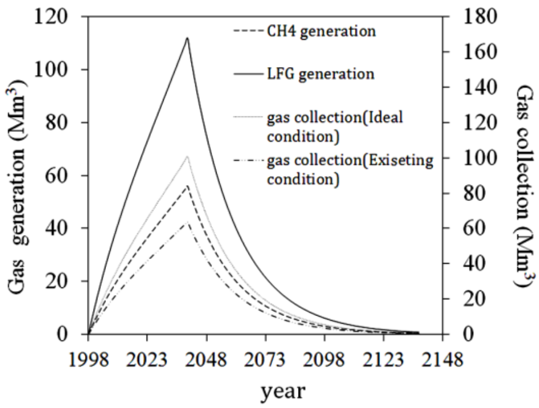

Figure 5. The rate of gas generation and gas collection from Shiraz landfill

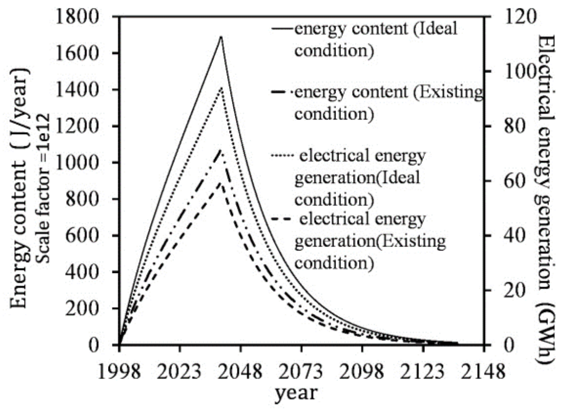

Figure 6. The energy content of the recovered biogas and the electrical energy generation of Shiraz landfill between 1997-2136

In fact, collection efficiency is defined as the percentage of the produced LFG in the landfill which is burned in flares or is restored for beneficial usages, such as electrical generation. Collection systems have a critical role in LFG to energy conversion process in many landfills because lack of LFG collection systems leads to the loss of a big fraction of the generated LFG which consequently, causes the emission of LFG to the atmosphere. For example, 25 landfills in California captured an average of 43m^3 methane per each ton of MSW and the rate of methane loss was estimated to be 82m^3 per each ton of MSW (Themelis and Ulloa 2007). Overall, more than 85% of the generated LFG can be restored in the landfills; of course, this number has been reported to be 90% in some cases. In unmanaged landfills, however, the maximum amount of this value has been estimated to be 50%. Briefly, the effective factors influencing the rate of LFG recovery percentage are: 1) the area covered by the collection system, 2) depth of solid waste buried, 3) type of landfill coverage, 4) landfill bottom liner, and 5) waste compaction (US-EPA 2009b). Mexico Landfill Gas model is software which not only estimates the rate of gas generation from a landfill, but it also estimates the efficiency of the collection system in capturing the generated gas (Wang-Yao *et al.*, 2006). According to the characteristics of Shiraz landfill (50% area with collective wells, 100% area with final cover, 100% intermediate cover, 100% daily cover, and 0% bottom liner) and considering the leakage of leachate from the bottom to underneath layers, the efficiency of LFG collection system was estimated as 57% by this software. In addition, considering the ideal condition scenario, the efficiency of LFG collection system was selected as 90% based on IPCC recommendations.

As demonstrated in Fig.5, the first and the second scenarios were significantly different regarding the rate of the collected gas. In fact, the rate of the collected gas between 1997 and 2137 was calculated 1.4 and

2.2 billion cubic meters in the existing and the ideal scenarios, respectively, which shows a difference of about 800 million cubic meters. Overall, having a plan for this amount of lost gas not only prevents the emissions of greenhouse gases and air pollution, but it will also have economic benefits. To achieve the ideal conditions, some measures, such as using bottom liners, subsurface and open drains systems, impermeable covers, increasing the depth of the landfill, and finally using vacuum systems for the generated LFG collection, are recommended.

By assuming 16.76 MJ m^{-3} energy content for LFG, it can be seen in Fig.6 that in both existing and ideal conditions, similar to the gas generation pattern, the maximum energy content will be in 2039 and then we will encounter a trend of decline until 2136. During the years that we will be encountered with gas generation, the total thermal energy content in both existing and ideal conditions will be 45.75×10^{15} and 72.32×10^{15} J, respectively which seems to be very high.

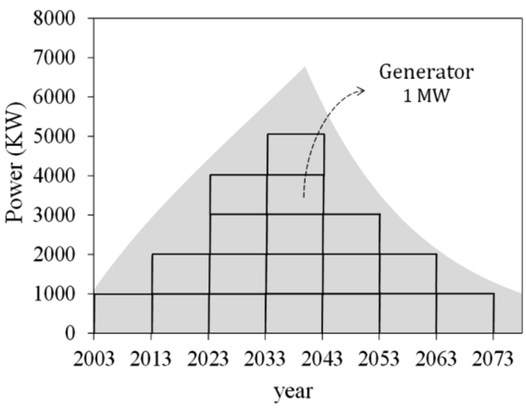

Figure 7. The number of the usable generators in the existing condition

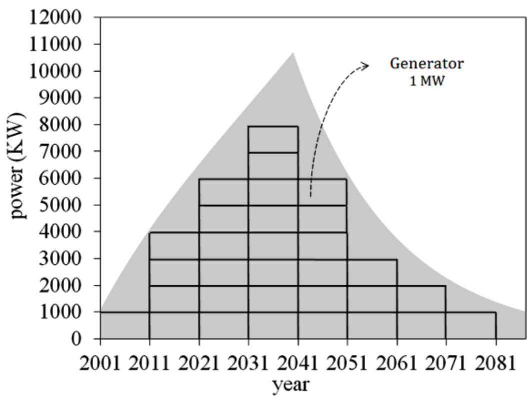

Figure 8. The number of the usable generators in the ideal condition

The rate of electrical energy produced from Shiraz landfill biogas was calculated according to 18004.5 KJ KWh^{-1} thermal conversion rate (Fig.6). The maximum electrical energy generation is similar to the pattern of gas production in the landfill and will be 2545GWh and 4019GWh for the existing and ideal conditions, respectively in 2039 and will decline afterwards. Based on the rate of electrical energy consumption per capita of 2800KWh $year^{-1}$ (Sadeghi *et al.*, 2011) and the average family size of about 4 people (Amini *et al.,* 2009) in Iran, the maximum electrical energy in existing and ideal conditions provides 21236 (84945 people) and 33536 (134124 people) families' electrical demand, respectively.

The power of internal combustion engines for generating electricity from LFG varies from 800 kW to 3 MW (US-EPA 2009a). Assuming the utilize of 1 MW generators and using each generators at full capacity, electrical energy production in existing and ideal conditions would begin in 2003 and 2001, respectively. As can be seen in Fig.7 and 8, by using the 1 MW generators and assuming 10 years for each generator's lifetime, the electrical energy generation could continue until 2073 and 2081 for existing and ideal conditions, respectively. Also, from 2031 to 2041 in the ideal condition and from 2033 to 2043 in the existing condition, the maximum number of the generators which could simultaneously be available will be 8 and 5 respectively. It should be noted that utilizing the generators with the power of less than 1 MW could lead to a greater use of the produced gas from the landfill; however, due to an increase in the number of the generators in operation, it could lead to the increasing costs of system maintenance and operation. Eventually, in order to achieve the maximum efficiency and benefits, it is recommended to select the type of the generators by an economic analysis and considering the variables, such as costs per capita, costs operation and maintenance, tax, fuel prices, and profit gained from annual electricity selling.

4. Conclusions

The present case study attempted to estimate the rate of LFG production in Shiraz landfill by first order model presented by USEPA. For this purpose the methane production potential and methane generation rate constant were estimated about $155.22m^3$ $year^{-1}$ and 0.053 respectively. Then by defining two scenarios (ideal and existing condition) for the LFG collecting system, the maximum generation of electrical energy from the collected LFG was estimated 2545GWh and 4019GWh for ideal and existing condition respectively. The results showed that further investment on the LFG collection system can significantly affect the collected LFG rate and subsequently influence the rate of the produced electrical energy. It seems that the recovery of biogas at Shiraz landfill could be a desirable alternative in different available waste management options for this city. On the other hand, utilizing of the LFG as a renewable energy at this site is not only economical, but it is also environmentally friendly.

Acknowledgements
We would like to thank Shiraz University of Medical Sciences for financial support of this research project. Hereby, the authors would like to thank the Municipality of Shiraz for their assistance in the research. Also, Research Improvement Center of Shiraz University of Medical Sciences and Ms. A. Keivanshekouh are appreciated for English editorial of manuscript.

References

Adl M.R. Godarzi-Rad, B. Boghlan-Dashti, S. Bozorgmehri and Lari H.R. (2005), Electrical Energy Generation Feasibility Study Results from Shiraz City Landfill. In *20th International Power System Conference*. Tehran.

Amini R., Bafandekar A., Binai A., Peirovi A. and Khodamoradi M. (2009), Integrated waste management plan of Shiraz city. Shiraz: waste management organization of the Shiraz Municipality.

Bicheldey T.K. and Latushkina E.N. (2010), Biogass emission prognosis at the landfills, *Int. J Environ. Sci. Tech,* **7**, 623-628.

Czepiel P.M., Shorter J.H., Mosher B., Allwine E., McManus J.B., Harriss R.C., Kolb C.E. and Lamb B.K. (2003), The influence of atmospheric pressure on landfill methane emissions, *Waste management,* **23**, 593-598.

Desideri U. (2003), Sanitary landfill energetic potential analysis: a real case study, *Energy Conversion and Management,* **44**, 1969-1981.

Di Bella G., Di Trapani D. and Viviani G. (2011), Evaluation of methane emissions from Palermo municipal landfill: Comparison between field measurements and models, *Waste management,* **31**, 1820-1826.

Faour A.A., Reinhart D.R. and You H. (2007), First-order kinetic gas generation model parameters for wet landfills. *Waste management,* **27**, 946-953.

Farzadkia M., Jorfi S., Akbari H. and Ghasemi M. (2011a), Evaluation of dry solid waste recycling from municipal solid waste: case of Mashhad city, Iran, *Waste Management and Research,* **30**, 106-112.

Farzadkia M., Karimaee M. and Karami M.A. (2011b), Investigation of methane emission potential for municipal solid waste landfill sites in Iran and declining approaches 2008, *Electronic Physician*, 380-391.

IPCC. 2000. Good practice guidance and uncertainty management in national greenhouse gas inventories[available at www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html].

IPCC. 2006. Guidelines for national greenhouse gas inventories:Intergovermental panel on climate change Japan: IGES.

Kamalan H., Sabour M. and Shariatmadari N. (2011), A Review on Available Landfill Gas Models, *Journal of Environmental Science and Technology,* **2**, 79-92.

Machado S.L., Carvalho M.F. and Gourc G.P. (2009), Methane generation in tropical landfills:simplified methods and field results, *Waste management,* **29**, 153-161.

Manna L., Zanetti M.C. and Genon G. (1999), Modeling biogas production at landfill site, *Resources, Conservation and recycling,* **26**, 1-14.

Mor S., Khaiwal R., De-Visscher A., Dahiya R.P. and Chandra A. (2006), Municipal Solid Waste Characterization and Its Assessment for Potential Methane Generation: A Case Study, *Science of Total Environment,* **371**, 1-10.

Nabizadeh R., Heidari M. and Hasanvand M.S. (2008), Municipal solid waste analysis in Iran, *Iran. J. Health & Environ,* **1**, 9-18.

Omrani G., Mohseni N., Haghighat K. and Javid A.H. (2008), Technical and health assessment of methane recovery from gas from Shiraz landfill, *Journal of Environmental Sciences and Technology,* **10**, 174-182.

Ozcan H.K., Nemlioglu S. and Demir G. (2007), Methan emission in landfill gas at two closed waste disposal sites in Istanbul, Turkey, *Journal of Scientific & Industrial Research,* **66**, 403-406.

Park J. and Shin H. (2001), Surface emission of landfill gas from solid waste landfill, *Atmospheric Environment,* **35**, 3445-3451.

Pichtel J. 2005. *waste management practices,municipal,hazardous,industrial*. Boca Raton, FL: Taylor & Francis Group.

Sadeghi H., Zolfaghari M. and Heydarizade M. (2011), Estimation of Electricity Demand in Residential sector using Genetic Algorithm Approach, *International Journal of Industrial Engineering & Production Research,* **22**, 43-50.

Salehi S., Dehghanifard E., Jonidi Jafari A., Atafar Z., Farzadkia M., Ameri A. and Nabizadeh R. (2011), Qualitative Assessment of Compost Products of Tehran and Khomein Facilities, Iran, *International Journal of Applied Environmental Sciences,* **6**, 81-86.

Stern J.C., Chanton J., Abichou T., Powelson D., Yuan L., Escoriza S. and Bogner J. (2007), Use of a biologically active cover to reduce landfill methane emissions and enhance methane oxidation, *Waste management,* **27**, 1248-1258.

Tchobanoglous G., Tcheisen H. and Vigil S. (1993), *Integrated solid waste management*. New York: McGraw-Hill.

Themelis N. and Ulloa P. (2007), Methane generation in landfills, *Renewable Energy,* **32**, 1243-1257.

Thompson S., Sawyer J., Bonam R. and Valdivia J.E. (2009), Building a better methane generation model: Validating models with methane recovery rates from 35 Canadian landfills, *Waste management,* **29**, 2085-2091.

Tsatsarelis T. and Karagiannidis A. (2009), Estimation of future methane production from Hellenic landfills, *Global Nest Journal,* **11**, 162-171.

US-EPA. 2005a. First order kinetic gas generation model parameters for wet landfills. In *EPA-600/R-05/072*. Washington, D.C.: United States Environmental Protection Agency.

US-EPA. 2005b. Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide In *EPA-600/R-05/047*. Washington, D.C.: United States Environmental Protection Agency.

US-EPA. 2009a. LFG Energy Project Development Handbook. Washington, D.C.: United States Environmental Protection Agency.

US-EPA. 2009b. User's Manual Mexico Landfill Gas Model Version 2.0 Washington, D.C.: U.S. Environmental Protection Agency.

Wang-Yao K., Towprayoon S. and Chienchaisri C., 2006. Seasonal Variation of Landfill Methane Emissions from Seven Solid Waste Disposal Sites in Central Thailand In *Joint International Conference on "Sustainable Energy and Environment (SEE 2006)"*. Bangkok Thailand.

Wangyao K., Yamada M., Endo K., Ishigaki T. and Naruoka T. (2010), Methane Generation Rate Constant in Tropical Landfill, *Journal of Sustainable Energy & Environment,* **1**, 181-184.

Zamorano M., Ignacio Pérez Pérez J., Aguilar Pavés I. and Ramos Ridao Á. (2007), Study of the energy potential of the biogas produced by an urban waste landfill in Southern Spain, *Renewable and Sustainable Energy Reviews,* **11**, 909-922.