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ORIGINAL ARTICLE

Assessment of landfill gases by LandGEM and energy recovery potential from municipal solid waste of Robat Karim

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Abstract
Enormous volumes of municipal trash created in the city of Robat Karim are annually digested by microorganisms in anaerobic disposal sites, resulting in large amounts of gas. The goal of this research is to use LandGEM software to estimate the quantity of methane gas generated by the Robat Karim landfill and the viability of extracting electricity from it. This descriptive cross-sectional research was conducted in the city of Robat Karim in the province of Tehran. Physical waste analysis was done as the first step of this investigation. The latest census in 2016 by The Statistical Center of Iran showed a population of 105,393 people in 31,803 households. It is located 27 km (17 mi) southwest of Tehran. The constant amount of methane emissions and the amount of methane production potential in the landfill of Robat Karim city were acquired in the third step, and the quantity of landfill gases was computed in the fourth stage by inputting the information received in the program. The landfill gases of Robat Karim city were explored by assuming a volume proportion of 50% methane and calculating 170 m^3/Mg as the gas production potential coefficient and 0.050 y^{-1} emissions as the methane production rate. According to the findings, the total quantity of landfill gas, methane, carbon dioxide, and non-methane organic matter in terms of mg per year was 3612, 9647, 2647, and 622, respectively, in 2022. It was discovered that the volume of landfill gases produced in Robat Karim city over time followed the standard trend of landfill gas production. Based on these findings, initiatives to utilize methane gas for energy production and measures to limit greenhouse gas emissions into the environment are recommended.

Keywords Urban gardens · Methane gas · Garbage dump · Greenhouse gases · Environment

1 Introduction

Given the limited supplies of fossil fuels and the pollution created by their usage, scientists all over the globe have been driven to explore alternatives to them [1] in this respect [2]. Biogas is a renewable energy source. On the other hand, due to the impending shortage of fossil fuels in human society, biomass (biomass), as well as the ease with which the biogas system may be used, has been widely used across the globe. Anaerobic fermentation, as a biological process for biogas generation from the biological breakdown of waste by microorganisms under situations of poverty or lack of oxygen, is a possible source of energy demand today, in addition to offering a solution to environmental concerns. Organic wastes, on the other hand, are unable to degrade properly owing to nutritional imbalances in microorganisms and a lack of or insufficient buffering capacity for chemical reactions [3]. Gas generation from landfills starts in the early months of the landfill's operation and may last for many years after it is closed. The composition of the gas changes throughout this time depending on the landfill's decomposition phase and includes air gases, ammonia, carbon monoxide, carbon dioxide, hydrogen, hydrogen sulfide, methane, nitrogen, and oxygen. Emissions from landfills, there are numerous significant reasons to think about landfill management, the most important of which being methane gas, which is the principal component of landfill gas. Methane accounts for 50–60% of the total landfill gas generated by anaerobic garbage decomposition. The remaining 50–40% is mostly carbon dioxide, with a tiny amount of other gases including hydrogen sulfide [4].

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1.1 Sanitary landfill

Landfilling that is subject to rigorous cleanliness requirements is classified as a sanitary landfill. These rules protect the environment against landfill risks such as leachate generation and leakage, as well as the discharge of dangerous gases into the earth's strata. Landfilling in a narrow valley, wet landfilling, landfilling of industrial waste, and unrestricted landfilling are all examples of sanitary landfilling. The technique of burying garbage in the earth is determined by the landfill's features and geology. Because proper and adequate attention was not taken in choosing the landfill in the past, it resulted in several difficulties; engineering procedures such as the placement of impermeable layers and the collection and treatment of leaking liquids are now employed to pick up the landfill. The hazards of non-compliance with sanitary standards in the disposal of municipal garbage are so great in most areas throughout the nation, particularly in towns with high groundwater levels, that authorities should pay greater attention to this critical subject. Many of the gases produced within landfills are explosive and combustible, causing environmental damage as well as presenting a major hazard to human health. Gas production occurs during the initial months of landfilling and may continue for many years after the landfill is closed. Methane gases, carbon dioxide and hydrogen gases, hydrogen sulfide, and volatile organic compounds, among others, are produced by a sequence of biochemical processes on biodegradable organic matter in garbage under anaerobic circumstances. Methane is the most common gas, accounting for 70–60% of the total. It may enter into the soil and replace oxygen in the soil, reducing plant development, in addition to its function as a greenhouse gas. Methane gas may spark fires and kill flora, particularly in forested regions.

1.2 Methane gas

The simplest alkane, methane (CH4), is a light, colorless, odorless molecule that is mostly utilized as a fuel. It is also known as swamp gas because it results from the decomposition of organic matter, such as the breakdown of plants and their decay, and because organic matter decomposes anaerobically (without oxygen) on the planet. He claims that methane is the most abundant gas on the planet. Wetlands and seas are the primary sources of methane generation, followed by human activities. This gas, also known as flammable gas or explosive coal mines, is the last step in the anaerobic decomposition of organic matter and plants, chemical fertilizers, municipal effluents and wastes, animal waste, and other materials. Arrives and brings the procedure to a close. Methane is lighter than water in the liquid phase, just as it is lighter in air than atmospheric gases. It may be dissolved by non-polar organic liquids such as gasoline, ether, and so on. After carbon dioxide and CFCs, this gas is the third and most well-known greenhouse gas. One of the sources of methane gas is methane hydrate, which is produced by mixing methane with deep-sea water. The world's greatest source of energy is methane hydrate, which is found as needle-shaped ice on the ocean bottom. These resources are so extensive that they may be compared to oil reserves.

1.3 Gas production process in landfills

Landfills are a source of methane generation as well. Depending on its structure, each material that enters the stage of disintegration and degradation produces distinct gases. Landfills are the primary source of these gases since they contain a large amount of garbage and leachate, among other things. LFGs are the total emissions from these facilities. CO_2, methane, VOCs, and other gases are among the most often generated in these facilities [5]. The sort of material buried in landfills has a direct impact on the pace and type of gas generated. The gas is created at a quicker rate when the substance decomposes. The pace of gas production is sometimes so rapid that burial may happen within months, and other times it might take years. The gases generated in these locations, despite their negative consequences on the environment and even human health, such as explosive characteristics, surface and groundwater contamination, carcinogenicity, and so on, are a major source of worry for human communities. However, if the extraction procedure is done efficiently in these locations, in addition to reducing the occurrence of these problems, the government will save money owing to the many uses of these gases, particularly methane gas. The quantity of methane produced in an environment is affected by a variety of parameters such as pH, type of environment (acidic or mildly acidic), amount of oxygen and hydrogen, temperature and humidity, and so on. The better the anaerobic bacteria function and the more methane is produced, the smaller the quantity of oxygen in the environment or the less it penetrates the burial layers. The optimal pH for methane-producing bacteria activity is between 6 and 8. The greater the humidity (up to 60%) and the substance, the more the atmosphere serves as an isolated habitat throughout the decomposition process, preventing oxygen from entering the burial sites and raising the ambient temperature. The best temperature for methane generation is between 30 and 40 degrees Fahrenheit. Material density and compaction will also play a key role in enhancing methane generation [4].

1.4 Anaerobic decomposition

Anaerobic decomposition is a kind of decomposition that takes place in the absence of oxygen and is carried out by anaerobic bacteria. Decomposition of materials that fit within this category occurs in three phases. The material is initially broken down into compounds such as volatile fatty acids, hydrogen, and alcohol by fermentation agents. Hydrolysis is the term for this sort of degradation. The substance is then broken down and transformed into acetic acid by acid-producing bacteria. Osteophilic and hydrophilic bacteria convert the materials of acetic acid and hydrogen to carbon dioxide and methane in the final step. The anaerobic process produces a variety of gases, including methane and other hydrocarbons; this sort of gas is known as biogas. The most common biogases are carbon dioxide and methane.

1.5 Energy production from methane gas

This gas is a fundamental element in the petrochemical sector, and it is extensively utilized in energy and fuel production, together with propane gas as a liquefied gas. This substance is a critical component in the production of organic compounds as well as a significant source of hydrogen gas [5]. Biogas from anaerobic decomposition has a variety of uses in energy generators [6].

As the world's population grows, so does consumption, resulting in a growth in the creation of urban and rural, domestic, agricultural, and industrial waste, posing a severe danger to the environment's health. Large volumes of methane gas, which has more severe climatic effects than other gases, enter the atmosphere each year when garbage from landfills ferments spontaneously. Various groups have traditionally prioritized environmental protection and mitigating extreme climate change. International organizations have put up specific plans and policies for member nations to safeguard the environment, particularly the reduction of greenhouse gases and the avoidance of environmental consequences, at numerous meetings (such as Rio and Kyoto). Reduced greenhouse gas emissions, the preservation of forests and pastures, the prevention of groundwater contamination, the elimination of viruses and weed seeds, and other environmental repercussions all need the employment of innovative energy production technologies.

Given the city of Robat Karim's proximity to Tehran and the city's population overflow, it is vital to investigate the state of its landfill. The Robat Karim cemetery also collects garbage from nearby cities. As a result, the quantity of methane gas generated from the Robat Karim landfill is evaluated in this research, as well as the feasibility of energy extraction from it, and the amount of methane gas produced is determined by modeling.

2 Research background

According to the findings of Sadeghi et al. [7] research in Saqez, trash production in the city is anticipated to rise from 62,050 tons in 2016 to more than 108,805 tons in 1413. This equates to an increase in methane gas emissions from 32 tons per hour in 2016 to almost 2203 tons per hour in 1413.

Salehion et al. [8] investigated the organic components of municipal solid waste in Karaj and their impact on biogas generation potential. Anaerobic digestion of municipal solid waste to create biogas is a tried and true method of generating energy from trash. Both in the winter and summer, components of the organic waste sector were detected in five categories. The performance of biomethane and the modeling parameters of biogas production kinetics were then tested in a promise test at mesophilic temperature at two concentration levels of 8 and 15 TS percent. Fruit and vegetable waste made up the greatest components in the organic waste division, accounting for 62.9% in the winter and 70.6% in the summer. Biomethane output was considerably different, at 8 and 15% TS, with 385.2 and 289.2 L/kg VS and 66.8 and 58.8% methane, respectively, although VS degradation was 87.49 and 84.72%. There was no discernible difference between the two. Continuous digestion is feasible for a period of 30 days in order to maintain steady biomethane output.

Rezaei and Mohammad Hassani [9] investigated the generation of environmental gases in the Shahinshahr landfill for the purpose of energy extraction in a research. The findings demonstrate that landfill gas emissions have been reduced over time. The maximum amount of methane and carbon dioxide generated was about 1,050,000 and 2,870,000 kg in 1394, while the lowest amount of methane and carbon dioxide produced was approximately 174 and 476 thousand kg in 1424. The total volume of gases generated in this landfill over 30 years is expected to be 46 million cubic meters, with methane accounting for 27% of the mass and carbon dioxide accounting for 73%. Over the next 30 years, methane and carbon dioxide emissions are expected to be 15 million and 42 million kg, respectively. The volume of landfill gases has reduced over time in general. To manage greenhouse emissions and provide the energy necessary by Shahinshahr Recycling Plant to consume this amount of gas, it is advised that energy extraction technologies be used.

The creation of biogas from plant and animal waste was researched by Mohammad Alikhan and Khorramnejadian [10]. The purpose of this research was to look into the generation of biogas from plant and animal waste at the Koreh Gaz tourist camp, which is located in the southern part of the Kavir plain. The digesting feed was chosen for this purpose by selecting a random sample of wet waste (mostly vegetable and summer components) and animal waste. Five steps were used to load the samples. The amount of methane and biogas generated, as well as its physical and chemical qualities, were all measured. The pH level in this procedure ranged from 5.8 to 7.5. The pH was steadily dropped in the early days, and the pH was monitored until the ninth day of acidic environment and low pH. The gas production curves for the whole 25-day loading period indicated a rise in gas production up to the 15th day of loading, and then a process of diminishing gas output from the 15th day of loading to the conclusion of the period, indicating that the system is stable. As a consequence, we can observe that the whole digestion process in an anaerobic system takes 15 days, as shown by an increase in the activity of methane-producing bacteria on the 15th day after loading.

Mohseni et al. [11] calculated the potential for methane generation from landfills in Iran's major cities (Tehran, Shiraz, Mashhad, Isfahan, Karaj). The quantity of methane and carbon dioxide generated from all 5 landfills is as described in Table 1

Also, above standards were vinyl chloride, butane, carbon disulfide, chlorofluoromethane, benzene, dichlorodifluoromethane, dichlorofluoromethane, hexane, pentane, and xylene pollution. The practical use of energy from this gas with an emphasis on purification and refining exhaust gas such as landfill Shiraz waste is a suitable option to remove this greenhouse gas due to the large amount of methane produced in the landfills of the mentioned cities and according to the piping measures that have been taken to extract gas in these areas.

Using LandGEM and Design Expert software and historical data, Jamshidi Zanjani and Rezaei [12] calculated the quantity of methane emissions from the Aradkooh landfill in Tehran. In this research, the factors impacting waste generation were investigated using LandGEM software from the US Environmental Protection Agency (EPA), as well as experimental design and statistical analysis software by Design Expert using historical data approach. The methane that was produced was thrown in the Aradkuh municipal trash landfill. Finally, the quantity of methane produced in area C of the Aradkooh landfill throughout the specified time period was computed and given in this paper. The model's findings show that methane gas production peaks at 10 m/year2.13 in the 1111 solar year.

Table 1 Methane generation in the different landfills (source: 11)

CH_4 (M^3/G)	CO_2 (M^3/G)	City name
8.25×10^7	11.15×10^7	Kahrizak
$9.6\times10^{5\ (KARAJ)}$	$1.5\times10^{6\ (SHIRAZ)}$	Shiraz and Karaj
…	$10^6\times8.46$	Esfahan
1.72×10^7	$10^7\times3.37$	Mashhad

Karbasi et al. [13] looked into the methane gas production capability of municipal solid waste in Langrood in order to reduce greenhouse gas emissions, safeguard the environment, and lower the cost of municipal solid waste management. Methane generation was measured at middle (about 35 °C) and high (around 65 °C) temperatures in this research. The findings revealed that methane production is more visible at low temperatures and that the created methane gas may provide 36 million kWh of power per year, which is almost 30% of Langarood's annual electricity usage.

Imrani et al. [5] looked at the extraction of methane gas from waste landfills in Shiraz. The Barmshour landfill holds the trash of 120,000 Shiraz residents, gathered from eight different districts. The plumbing for extracting gas from this site's burial has been completed. Per ton of municipal garbage, the realistic amount of gas reclaimed from the landfill is 40 to 400 cubic meters. In 1999, the first phase of the landfill gas collecting project was completed in the landfill's western section. In the year 2000, work on gas extraction pipelines started. In the third and fourth levels, 11 series of V-shaped mesh pipes with angles and slopes less than 15C are installed in the floor and reinforced with sand-cement mortar and carcass stone. Gas extraction pipelines have been placed in the same manner in the following strata. According to landfill gas studies, there is 61% methane and 24% carbon dioxide. Each cubic meter of gas recovered from trash creates 22.5 kWh of power or around 75 kWh per day if the efficiency is estimated to be 30%. The power produced in Shiraz will be utilized to build a industrial recycling complex, water wells, and a burial site lighting system. This study looked at the current state of methane gas extraction from technical, economic, and health perspectives, and it was presented using data analysis and effective factors on gas extraction rate, as well as a theoretical and experimental framework.

Khazaei et al. [14] in a research evaluated the potential of renewable energy resources and their power plant capacities in Iran, and the results showed that over the past 20 years, 1.5% of Iran's electricity production is provided by renewable energies. Iran also has much more potential to use renewable energy. By 2020, Iran has a potential of 42,000 MW of renewable energy. But, the capacity of renewable power plants built in Iran is 800 MW.

The results showed that the research of Zahedi et al. [15] titled simulation and optimization of electricity production by the energy waste unit in Tehran showed that the amount of steam produced by the boiler to cool the furnace exhaust gases from 750 to 300 °C is equivalent to 298 tons. It is during the day. This amount of steam has a pressure of 24 and a temperature of 350 °C. The steam sent to the turbine produces 4 MW of electricity. The waste burned per day is equivalent to 180 tons, which requires 1200 tons of air per day to carry out the combustion process. After completing the simulation, it was found that the obtained turbine power is equal to 4.052 MW, which has an error value of 1.34%, and the furnace power is equal to 67,510,000 kJ per hour. Finally, the simulation was optimized to produce 19 MW of electricity, and waste discharge was determined to increase from 180 to 879 tons per day.

The results of Zahedi et al.'s research [16] titled Feasibility of Biodiesel Production from Oilseeds in Tehran Province showed that parts of the western and central regions of Tehran Province are suitable for cultivation of oilseeds to be used for biodiesel production. However, about 90% of the areas of Tehran province are unsuitable for cultivating oilseeds. The biggest limiting factor is the soil texture of Tehran province, more than 50% of the surfaces of Tehran province have unsuitable soil texture for growing oilseeds. In order to identify the optimal areas for planting oilseeds, the average cost variable of (Cave) per liter of biodiesel is introduced. The results show that according to the costs of production, transportation, distribution and supply of raw materials, producing biodiesel in these areas is cost-effective when the average variable cost is less than 92 thousand rials per liter of biodiesel produced.

In research, Vahabi khah et al. [17] investigated the forecasting of the use of renewable energy in the water and sewage industry. The results showed that increasing the carbon tax to more than 30 USD per ton of CO_2 can reduce greenhouse gas emissions from fossil fuel power plants by 30%.

3 Materials and methods

The style of research in this study is descriptive-analytical of the applied type, and it was developed and compiled from the LandGEM software package by the Technology Control Center of the US Environmental Protection Agency, and it may be used as an estimating tool to simulate landfill gas emissions. To be utilized are urban solids. This software application can estimate the quantity of 46 instances of air pollutants and landfill escape, in addition to measuring the amount of gas generated by landfills.

LandGEM applies the first-order decomposition equation to estimate the annual gas. The major parameters of the model are k and L0.

$$Q_{CH4} \sum_{i=1}^{n} \sum_{j=0.1}^{1} kl_0 (\frac{mi}{10}) e^{-kt_{ij}}$$

$\mathbf{Q_{CH4}}$: Annual methane production per year calculated (cubic meters per year).

i: Increase in one year.

n: (year of calculation)—(first year of waste acceptance).

J: 0.1 time increase per year.

k: Methane production rate (Year-1).

$\mathbf{L_0}$: Methane production potential (m3 / Mg).

$\mathbf{M_i}$: Waste mass accepted in year i (Mg).

$\mathbf{t_{ij}}$: age of section j of waste Mi accepted in year i (decimal years, eg., 3.2 years).

Estimated potential of methane production at the traditional landfill of Iranian cities (L0):

L00, the amount recovered from each ton of garbage, is determined using the following ratio based on the content of the waste, the status of landfills in Iran, and environmental conditions in line with the IPCC (International Panel on Climate Change) standard of 1996:k

$$L_0 = \mathbf{MCF} \times \mathbf{DOC} \times \mathbf{DOCf} \times \mathbf{F} \times 16/12 \times (1 - \mathbf{OX})$$

The values of the above parameters are as follows:

DOC: Organic carbon content, which is an important component of gas production estimates, is degradable in trash, and small variations in the quantity of DOC may result in substantial changes in methane gas estimations.

Because the composition of trash varies by country, DOC values vary highly; hence, it is best to go by the real facts when identifying this parameter. The resultant DOC amounts of food waste and paper and cardboard will be (0.28) and (0.02), respectively, based on IPCC recommendations and physical waste analysis in the surveyed cities, and the final DOC value for landfills in cities 3/0 will be specified.

MCF: Methane production correction factor 0.8 (this coefficient is confirmed by the New Energy Organization).

DOCf: This is the percentage of organic matter that can be converted to methane and carbon dioxide. The value of this coefficient is defined in terms of burial temperature as follows:

$$\mathbf{DOCF} = 0.14\mathbf{T} + 0.28$$

Proposing an average temperature of 35 degrees, the DOCf coefficient is computed to be about 0.84.

F: The percentage of methane in landfill gas, which is 61% applying landfill gas analysis in Iranian cities.

OX: Oxidation rate in burial layers.

Regarding the high depth of trenches and layers, oxidation is regarded in the zero calculations.

As a result of the computations, the L0 value for municipal garbage is 164 m^3/ton. Using the first degree equation for gas production might result in up to a 22% inaccuracy rate.

Constant methane production rate:

The gas production regime in the landfill is determined by the methane production rate constant (k), which rises with rising gas velocity; in other words, raising the value of k generates more gas in a given period of time and a specific quantity of garbage under the same circumstances from 0.003 to 0.21 is thought to represent the k range (10).

As a result, the quantity of methane produced will be determined by the humidity in the waste, as well as the temperature and pH. Given all of the constraints, the value of y-105/0 will be appropriate for k.

3.1 Study location

Tehran province is located in the northern part of Iran and the southern range of the Alborz mountains. Robat Karim city is one of the cities of Tehran province, which is located at an altitude of 5701 m above sea level. It is located in the southwest of the province and has an area of 501 km^2, length 1515, and width 81153.

Robat Karim city with a population of 629,314 people (based on the statistics announced by Tehran province in 86) in an area of about 324 km^2 placed in the southwest of Tehran province with three central parts, Golestan and Bustan, with an average of 4294 tons per year and daily average 357 tons of ordinary waste and 500 kg of hospital and medical waste; all of which will be conveyed to the Shoor River burial center placed in the southwest of the city and in the lands along this river with coordinates N 350 25 44.6 and E 50 58 16.5.

The 200-ha center lies 12 km southwest of Robat Karim city, 2 km east of Parand industrial town, and 3 to 5 km from Parand's new city, at a distance of 900 m from the seasonal river water line (although it is located on the old bed of the river). Since 1979, Robat Karim Municipality has been preparing the facility without doing an environmental impact assessment (EIA), and it has been in operation since 2001.

Table 1 shows that 75.61% of trash is perishable, 6.34% is paper and cardboard, 11.8% is rubber and plastic, 3.1% is textile, 2.27% is glass, and practically 1% (0.88) is metal related, as illustrated in Fig. 1. As can be observed, perishable items generate the greatest waste, whereas metals generate the least.

According to the data in Table 2, about 118,669 tons of waste are buried in the Robat Karim municipal landfill each year, with an average daily landfill of 325 tons of garbage, more than half of which is connected to garbage. Effective factors such as the absence of disposal centers in the cities of Tehran province, easy road access for other cities, the introduction of the Rabat Karim center in the comprehensive waste management plan as a disposal center in the southwest of Tehran has increased the annual waste disposal rate in that center.

Table 3 shows the production of gaseous pollutants in landfills. The weighted average molecular weight of the total molecular weight of methane and carbon dioxide is used to calculate the molecular weight of the gas generated at the landfill. The molecular weight of 30.03 shows that

Fig. 1 Transfer route of temporary stations in Robat Karim city (source: research findings)

Table 2 Physical analysis of waste in Robat Karim city (source: Comprehensive Waste Management Center of Iran, 2013) (source: research findings)

Observation in the garbage	Composite components of waste materials	Row
75.61	Perishable material	1
6.34	Paper and cardboard	2
11.8	Rubber and plastic	3
3.1	textiles	4
2.27	Glass	5
0.88	Metals	6

Table 3 Information on the volume of waste input per year (source: research findings)

Year	Short tons/year	Mg/year
2001	3840	3490.909091
2002	5900	5363.636364
2003	7924	7203.636364
2004	9960	9054.545455
2005	11,985	10,895.45455
2006	12,125	11,022.72727
2007	14,214	12,921.81818
2008	15,465	14,059.09091
2009	17,892	16,265.45455
2010	19,421	17,655.45455
2011	27,352	24,865.45455
2012	34,964	31,785.45455
2013	57,125	51,931.81818
2014	157,676	143,341.8182
2015	215,948	196,316.3636
2016	277,130	251,936.3636
2017	273,750	248,863.6364
2018	296,650	269,681.8182
2019	277,400	252,181.8182
2020	292,000	265,454.5455
2021	283,000	257,272.7273
2022	299,000	271,818.1818
Mean	118,669.13	107,881.03
std	127,242.53	115,675.03

there is 50% methane and 50% carbon dioxide present. The molecular weight of the total gas generated at the landfill is modified if the methane content parameter in the model is changed by 50%, indicating the existence of fresh methane content. The total methane emission arising out of an open dumpsite is dependent on the total waste disposed at the site and its characteristics. Hence, a direct numerical comparison of methane estimations from various studies may be inaccurate. Hence, often the methane estimation potential is determined is as the ratio of the total methane emissions to the MSW generated. It was observed from the ration that the results obtained for present study location were comparable to the methane emissions from the dumpsites in Delhi (Table 2).

One of the main reasons for the increase in waste transportation to the Rabat Karim landfill in recent years is the increase in the population and the desire of surrounding communities to bring their waste to this city. On the other hand, the preparation of a comprehensive waste management plan by Tehran Governorate and the designation of Rabat Karim landfill to cover about 13 towns and surrounding villages has resulted in about 1.7 million people being covered by this center. It is also predicted that the population in this area will grow to 2,500,000 people by 2029 and the amount of discarded waste will reach more than 1200 tons per day. This problem shows the importance of finding solutions to reduce waste materials and establish energy conversion facilities. NMOCs and other air pollutants contained in Table 4 which is based on LandGEM software output information.

4 Discussion

Iran is one of the first 5 countries with natural resources in the world. Unfortunately, this problem has caused the relevant institutions to not be very interested in using the cycle of recycled materials from waste, because natural resources provide them with sufficient raw materials. This study is a blow to the relevant institutions, especially the municipalities, which unfortunately pay billions of dollars for waste disposal every year. In fact, instead of using their financial resources in the development of cities, they spend on waste management. Therefore, the purpose of this study is to create a clear perspective on reducing financial, environmental, and social costs for decision-makers, which will change their views by explaining the benefits of doing the project. Like Germany, which earns nearly 70 billion euros annually from waste, or China, which earns 40 billion dollars from this industry.

Figure 2 shows that the trend of landfill gas generation during the years of operation is not consistent. According to the composition of waste materials in Robat Karim city and based on the parameters and model used in this research, the maximum amount of gas emissions in this city in 2022 was the total amount of LFGs, methane, carbon dioxide, and non-methane organic matter in mg in 2022. This year's temperatures were 4.247E + 05, 7.775E + 02, and 1.827E + 00, respectively, and Fig. 3 revealed that LFG production peaked between 2011 and 2021, after which it began to decline. Because the average value for the quantity of material changes and other changes is taken into account, the composition of the gases generated and their changes are almost comparable, as shown in Fig. 4. Non-methane organic matter generation, while its tiny volume, may have carcinogenic implications in terms of significance and health impacts.

In general, the rate of organic matter biodegradation and gas generation in landfills is determined by the distribution of organic matter in the landfill, the availability of nutrients, moisture, and the landfill's initial density. Under typical conditions, the rate of decomposition of organic waste at the landfill site (as measured by gas production) would peak in the first 2 years and then gradually decline, generally over a period of 25 years or more. Gas output surged rapidly from 2001 to 2021 in the current research, then started to fall. It is conceivable that part of the debris will not degrade after years if moisture is not provided to the compacted landfill. The peak gas production rate in the first year is based on the suggested models to analyze the rate variations of gases generated by quick decomposition (decomposition in less than 5 years) and slow decomposition (decomposition in 5 to 50 years) of materials in landfills, respectively. The fifth happens following the production of natural gas. Gas production is considered to have begun at the conclusion of the first year of Landfill operation in these models. Other research has discovered a similar pattern.

Unsanitary waste landfilling in the city of Robat Karim, which is deposited in the open air, is now a major environmental issue. When it comes to landfill management, there are two options for dealing with the issue of landfill exhaust gas. The first process is the standard one, which entails extracting LFG and incinerating it. Carbon dioxide and water are the principal byproducts of this approach. In this approach, the world's landfill emissions are considerably decreased. The second technique is identical to the first, except that instead of being burnt, the recovered gas is utilized in commercial activity. Based on the quantity of methane generated in the Kuhdasht city dump and the cost of both technologies, one of them may be employed to control the gases in the Robat Karim city landfill.

Currently, in developed countries, the waste production rate per person is 250 g. Meanwhile, this rate in Iran has reached 800 g per day in some parts of the country. Rabat Karim disposal center, as the main disposal center in the southwest of Tehran province, receives about 1000 tons of urban waste daily. This high production rate sounds the

Table 4 gas/pollutant date estimation which has shown by LandGEM software after entering information from Robatkarim landfill

Combination	Concentration based on ppmv	Molecular weight
Total landfill gas		30.03
Methane		16.04
Carbon dioxide		44.01
NMOC	600	86.18
1,1,1-Trichloroethane (methyl chloroform) – HAP	0.48	133.41
1,1,2,2-Tetrachloroethane—HAP/VOC	1.1	167.85
1,1-Dichloroethane (ethylidene dichloride)—HAP/VOC	2.4	98.97
1,1-Dichloroethene (vinylidene chloride)—HAP/VOC	0.20	96.94
1,2-Dichloroethane (ethylene dichloride)—HAP/VOC	0.41	98.96
1,2-Dichloropropane (propylene dichloride)—HAP/VOC	0.18	112.99
2-Propanol (isopropyl alcohol)—VOC	50	60.11
Acetone	7.0	58.08
Acrylonitrile—HAP/VOC	6.3	53.06
Benzene—no or unknown co-disposal—HAP/VOC	1.9	78.11
Benzene—co-disposal—HAP/VOC	11	78.11
Bromodichloromethane—VOC	3.1	163.83
Butane – VOC	5.0	58.12
Carbon disulfide—HAP/VOC	0.58	76.13
Carbon monoxide	140	28.01
Carbon tetrachloride—HAP/VOC	4.0E-03	153.84
Carbonyl sulfide—HAP/VOC	0.49	60.07
Chlorobenzene—HAP/VOC	0.25	112.56
Chlorodifluoromethane	1.3	86.47
Chloroethane (ethyl chloride)—HAP/VOC	1.3	64.52
Chloroform—HAP/VOC	0.03	119.39
Chloromethane—VOC	1.2	50.49
Dichlorobenzene—(HAP for para isomer/VOC)	0.21	147
Dichlorodifluoromethane	16	120.91
Dichlorofluoromethane—VOC	2.6	102.92
Dichloromethane (methylene chloride)—HAP	14	84.94
Dimethyl sulfide (methyl sulfide)—VOC	7.8	62.13
Ethane	890	30.07
Ethanol – VOC	27	46.08

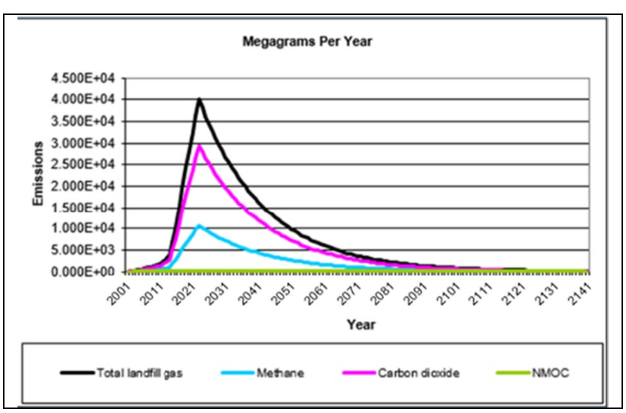

Fig. 2 Amounts of gases produced in the landfill of Robat Karim city in terms of mg per year

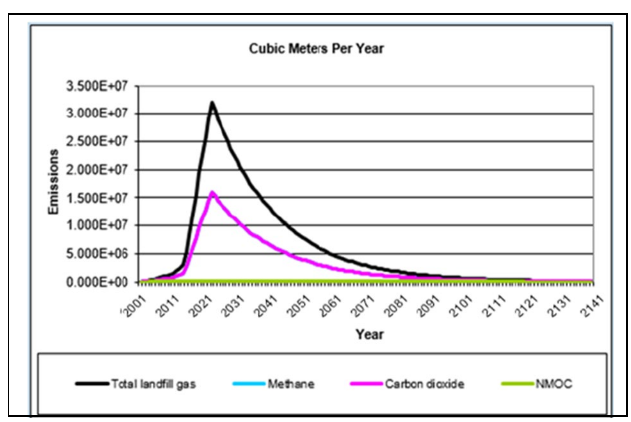

Fig. 3 Amounts of gases produced in the landfill of Robat Karim city in terms of cubic meters per year

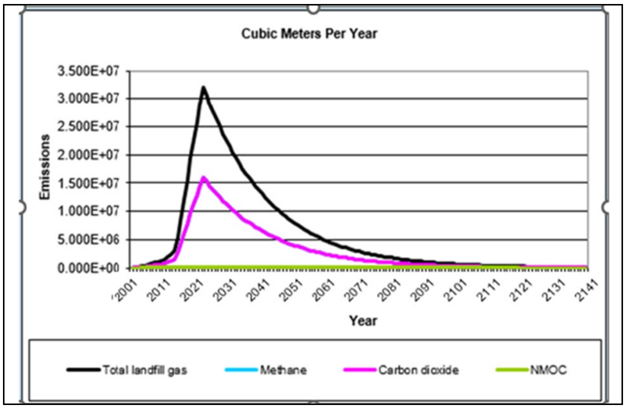

Fig. 4 Amounts of gases produced in the landfill of Robat Karim city in terms of units specified by the user

alarm about environmental disasters. Considering the daily burying of 1000 tons of waste, 11 million and 100 kg of carbon dioxide gas and 500 tons of leachate are generated every day, and these materials enter the environment of the region without any control. In fact, the time has come to turn this threat into an opportunity by looking into the future and take action to eliminate social, economic, and environmental costs. In the first stage, all provinces should prepare a comprehensive waste management plan, which is a legal requirement in the waste management law, and with the approach of reducing disposal sites from around 700 centers to 200 centers. In the second stage, to invest in energy conversion facilities from waste and build 200 energy conversion centers with the approach of producing electricity and ash from waste. In the third stage, all the produced electricity will be purchased by the electricity department as a guarantee, and its ash will be used in various industries, including the production of construction materials, asphalt production, etc. In the fourth stage, which seems to be the most important stage, knowledge-based companies will work to make maximum use of outgoing materials and produce new materials and create a big revolution in the waste industry. This revolution can play an essential role in generating wealth, eliminating unemployment, reducing foreign dependence, etc.

5 Conclusion

Landfills are one of the most significant sources of greenhouse gas emissions that can be minimized with proper management and recycling. The amount of leachate and biogas produced depends on the amount and type of organic matter in the waste, as well as the moisture inside the landfill. This waste disposal technique can become an environmental disaster if the processes of landfilling, gas collection, and landfill leachate are not properly executed. The objective of this study was to calculate the amount of gas in Robat Karim Municipal Landfill from 2001 to 2022. The amount of biodegradable components of garbage accounts for most of the gases released in the landfill. According to the results of this study, about 75% of the garbage in Robat Karim is biodegradable. This percentage of biodegradable materials is practically comparable to other cities in the country, such as Sanandaj, Shiraz, and Qom. In Sanandaj, for example, the share of biodegradable materials was estimated at about 70% in 2013.

The main differences in the rate and amount of gas evolution in a landfill are determined by material composition and environmental conditions, as indicated by the model coefficients used to estimate landfill gases. Table 2 also shows the variation of my normal values for different waste types as a function of degradability (source: research findings). Changes in these coefficients vary with circumstances and directly affect the amount of ML (coefficient of gas production potential) and k (methane production rate) since these two elements, i.e., Lo, are the most important and effective factors. As for the amount of methane released, the pH, temperature, humidity, and nutrients necessary for methane-producing bacteria affect the value of k. Methane production potential ranges from 0.02 in dry environments to 0.7 in wet environments, with more methane often produced in wet environments due to leachate recovery and higher waste decomposition. Under the circumstances, the value of k is equal to (y-1 0.050) and the value of Lo is 170 m^3 per mg/m^2, which corresponds to the garbage of the city of Robat Karim, as shown in Table 3. It belongs to the category of materials that decompose rapidly in landfills. The value of the coefficient k is on the same order of magnitude as other studies in the country and abroad. Rezaei et al. [9] found the same amount of methane in Sanandaj domestic waste (y-1 0.045), but we found it in the range of 125 to 310 m^3 per ton. The values of L0 (0.05 y-1) and 170 m^2/Mg, respectively, were studied in the Malaysian police investigation by Fard et al. [10]. In their investigation in Ahvaz, Mehdipour et al. looked at the levels of Lo (0.05 y-1) and 170 m^2/Mg, respectively. The values of these two factors affecting the amount of gas emissions are almost in the range due to differences in the overall quality of waste and environmental conditions of the study site, and the results of this study are in the range of other studies in other parts of Iran, according to Imrani et al. [5] in Shiraz. This study's findings may also be compared to those of Sadeghi et al. [7], Rezaei and Mohammad Hassani [9], Mohseni et al. [11], Salehiun et al. [8], Jamshidi Zanjani and Rezaei [12], and Imrani et al. [5].

Author contribution Seyyed Akbar Ebrahimi (First author): main researcher, Phd student; Shahrzad khoramnejadian (supervisor); Seyed Reza Asemi Zavareh (advisor); and Azita Behbahanina (advisor). This article is extracted from Seyyed Akbar Ebrahimi's doctoral thesis.

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Data availability That this declaration is not applicable.

Declarations

Ethical approval This collection has not been published in whole or in part in other publications. Nor has it been submitted to another journal for review or publication. In addition, the scientific materials are the result of the work of the authors, and they are responsible for the accuracy and validity of the results.

Competing interests The authors declare no competing interests.

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