Journal of Air Pollution and Health (Summer 2016); 1(3): 191-204

Original Article

Available online at http://japh.tums.ac.ir

THE MODELING OF CARBON DIOXIDE, METHANE AND NON-METHANE ORGANIC GASES EMISSION RATES IN SOLID WASTE LANDFILL IN CITY OF JAHROM, IRAN

*Amirreza Talaiekhozani[1], Ali Nasiri[2]**

[1] Civil Engineering Department, Jami Institute of Technology, Isfahan, Iran
[2] PhD Student of Environmental Engineering, Postgraduate School of Islamic Azad University Branch of Bushehr, Bushehr, Iran

ARTICLE INFORMATION

Article Chronology:
Received 03 March 2016
Revised 13 July 2016
Accepted 02 August 2016
Published 31 August 2016

Keywords:
Methane gas; Jahrom; sanitary waste disposal; gas emission

CORRESPONDING AUTHOR:
nasiri1064@gmail.com
Tel: (+98 31) 52636319
Fax: (+98 31) 52636320

ABSTRACT:

Introduction: Under the influence of existing microorganisms in soil, the landfilled municipal solid waste, would produce and release high quantities of carbon dioxide, methane and non-methane organic compounds into the atmosphere in anaerobic conditions. The aim of this study was to estimate the amount volume of produced gasses in the landfill located at city of Jahrom.
Materials and methods: To conduct this research, the primary data including waste composition, waste density, waste production capitation, the weight of the annual produced waste were collected using experimentations and calculations. These data were then used in LandGEM for the purpose of landfill gases volume estimation. The Screen view was then used for modeling of pollutants dispersion into atmosphere in 15 km radius around the landfill.
Results: Studies suggest that the waste generation in city of Jahrom is 313.35 g/person.d. The climax of carbon dioxide and methane production in this landfill in 2028 was equal to 10570000 m^3/year. Estimation shows that by recycling the obtained methane in this landfill, it is possible to generate 8375 MW of energy by 2016. It is also indicated that the concentration of produced pollutants in the landfill is calculable in 15 km radius.
Conclusions: The obtained results from this study could be used to determine the role of Iran in global emission of greenhouse gasses and be considered for the Iranian energy production planning's.

INTRODUCTION

The greenhouse phenomenon is the most important global concern in recent years [1]. The principal greenhouse gasses are carbon dioxide, chlorofluorocarbons, methane and nitrous oxide. The ratios of these gasses are: 57% carbon dioxide, 25% chlorofluorocarbons, 12% methane and 6% nitrous oxide [2]. Methane is one of the most important greenhouse gasses. Although the methane's ratio of production is the second rated after carbon dioxide, the warming potential of methane is 25 to 30 times higher than carbon dioxide [3-7].

One of the main sources of methane emission is solid waste landfills. According to a report, about 18.1% of the produced methane was as the result

Please cite this article as: Talaeikhozani A, Nasiri A. The modeling of carbon dioxide, methane and non-methane organic gases emission rates in solid waste landfill in city of Jahrom, Iran. Journal of Air Pollution and Health. 2016; 1(3): 191-204.

of anaerobic reduction of solid wastes in landfills by microorganisms present in the soil which led to the emission of carbon dioxide and methane in large quantities and production of other gasses such as hydrogen sulfide, nitrates, nitrites and non-methane organic compounds in smaller quantities [8].

The warming potential of every cubic meter of methane is equal to the warming potential of every liter of kerosene thus the recycling this gas can be economically beneficial. In cases where methane is not collected, by being and released into the atmosphere there is a heightened risk of fire in concentrations between 5 to 15%. Although, the non-methane organic compounds like vinyl chloride or benzo[a]pyreneare emitted from landfills are in low concentrations, this compounds are still very dangerous and possess carcinogenic risks. Based on this reasoning the estimation of production and emission of gases through anaerobic biodegradation of municipal solid wastes are highly important. On the other hand the calculation of emitted carbon dioxide and methane from landfills can help determine the role of Iran in emission of greenhouse gasses. There are several parameters that affect the quantity of the gasses produced through anaerobic decomposition. Many researchers were conducted a study on the effect of leachate recession of waste on the production rate of biogas. During this research, it was determined that the leachate recession of waste could lead to the increment of produced biogas and specially methane in landfills. However uncontrolled recession of leachate can lead to the inhibition of bacterial activity and reduced ratio of biogas production [9]. Other researchers used first-order decomposition rate equation in order to determine the ratio of emitted gasses from landfills. These researchers concluded that the ratio of methane production in rainy regions is equal to 0.23 /day and in arid regions is equal to 0.2 /day and in dry regions is equal to 0.18/day. There are several ways to calculate the methane ratio of emission which includes: landfill evaluation, field investigation and mathematical modeling [10].

The LandGEM can calculate and estimate the ratio of annual emission of produced gasses in disposal sites based on first-order decomposition rate equation. This software was developed by United States Environmental Protection Agency (US EPA) and was employed in several studies to estimate the ratio of produced for gasses in urban solid wastes landfills [11]. For instance, in previouse studies, it was reported that in the city of Najafabad 100% of collected waste is recycled and not landfilled. It was hypothetically considered a case where no recycling is done in the city of Najafabad and all collected solid waste are landfilled. Accordingly, it was modeled the production ratio of carbon dioxide and methane and 48 other non-methane organic compounds. Study results suggested that in the case where no recycling is done, in the course of 20 years, 107206 tons of carbon dioxide, 39074 tons of methane would be released into the atmosphere. Furthermore, the modeling results shows that in 2015, nearly 94 tons of dangerous non-methane organic compounds would enter the atmosphere of Najafabad which is prevented by 100% recycling of solid waste [12]. Other researchers modeled the ratio of pollutant gasses in landfill of Shiraz. The modeling results showed that every year of methane and of carbon dioxide enter the atmosphere of Shiraz from its landfill [13]. In other research, it was reported that tons of biogas and tons of carbon dioxide will enter the atmosphere of Rasht in 40 years of activity in its solid waste landfill [14]. Similar studies were conducted in Mashhad and showed that large quantities of gasses are being release into the atmosphere due to anaerobic activities in solid waste landfill [15]. In further studies, it was calculated the ratio of gas emission in city of Tehran. Based on the calculation a ratio of 558 m^3/h of methane will be produced in solid waste landfill of Tehran between the years 2000 and 2100 which is equivalent to 2354 MW of energy. Furthermore it was determined that during the course of these 100 years 93700000 tons of carbon dioxide would be entered the atmosphere [16]. US EPA in 2006 calculated the potential production capacity of several regions of Central

America using LandGEM which was estimated at 78 to 101 m^3/ ton of solid waste [3].

Although, several studies has been conducted on the ratio of pollutant gasses in solid waste landfills, no study has been conducted on the city of Jahrom. Also in none of these studies the dispersion of produced pollutant gasses around the solid waste landfill has been evaluated. Therefore the aim of this study was to estimate the ratio of produced carbon dioxide, methane and 48 other non-methane organic compounds in solid waste landfill of Jahrom and evaluation of their emission into the atmosphere. In this study, the LandGEM was used to estimate the ratio of emitted gases from the solid waste landfill of Jahrom. After that, obtained data from the LandGEM was used to model the dispersion of pollutants using Screen View.

MATERIALS AND METHODS

This study was conducted on the solid waste landfill of city of Jahrom in Iran. The population of Jahrom is 160210 and is located in the south of Fars province. The first step in this study is sampling the municipal solid wastes in city of Jahrom using mentioned methods in a research [17]. For this purpose, 4 municipal solid waste collection trucks were selected for sampling. These trucks dispose three loads gathered from the city each day in special container with specific capacity. The unloaded solid wastes were weighed and the density was calculated by considering the volume of the container. This was continued for a year once a month. It is worth mentioning that the sampling of solid waste was not carried out before or after the holidays in order to ensure the least possible error margin in sampling. Furthermore, a composite sample was extracted from the solid waste to determine the quality and the quantity of the composed mass using the purposed method by researchers in previous studies [17] including the perishable and non-perishable percentage, the percentage of humidity and the ratio of organic and inorganic compounds.

The second step in this study was to collect the required information from Jahrom's municipal recycling organization including the dimensions and volume of the Jahrom's landfill. After that, according to the population of Jahrom and population growth rate coefficient, the population of the city was estimated for upcoming years. Eq.(1) was used to estimate the population of the city:

$$P_n = P_0(1 + r)^n \qquad (1)$$

Where P_n is the population in year n, P_0 is the population in the source year, r is the average population growth rate and n is the number of years. It is assumed that the rate of solid waste generation of Jahrom city is constant and then the solid waste generation during different years was calculated.

In the third step, the constant ratio of emission for methane gas and the potential production ratio of methane in the landfill of Jahrom was determined using data obtained from areas including: underground water table, soil breed, the type of management employed in disposal centers, precipitation rate, soil type and employed texture in disposal site. Finally, by entering the acquired data into the LandGEM the ratio of emission in waste disposal site of Jahrom were estimated. The LandGEM uses the Eq.(1) to estimate the gas produced:

$$Q_{CH_4} = \sum_{t=1}^{n} \sum_{j=0.1}^{1} kL_0 \left(\frac{M_i}{10}\right) e^{-kt_{ij}} \qquad (2)$$

where is annual methane generation in the year of the calculation (in m^3/year); "1 year step" suggested, as in i is the time increment index with a 1 year step; n is (year of the calculation) - (initial year of solid waste acceptance); j is 0.1 year time increment; k is methane generation rate ($year^{-1}$); L_0 is potential methane generation capacity (in m^3/ton); M_i is mass of solid waste accepted in the i^{th} year (ton); t_{ij} is age of the j^{th} section of solid waste mass and M_i accepted in the i^{th} year (in tenths of a year, e.g., 3.2 years). The calculation was performed by entering the data acquired from the disposal site properties according to the Table.1

Table 1. Landfill Characteristics

Landfill open year	2010	
Landfill closure year (with 80-year limit)	2030	
Actual closure year (without limit)	2030	
Have model calculate closure year?	No	
Waste design capacity		ton
Methane generation rate, k	0.050	$year^{-1}$
Potential methane generation capacity, L_o	170	m^3/ton
NMOC concentration	4,000	ppmv as hexane
Methane content	50	% by volume

In this study, The Screen View was applied to investigate the dispersion of carbon dioxide, methane and NMOCs into the atmosphere. The presented presumptions in Table 2 were used in this software.

RESULTS AND DISCUSSION

The calculation of population during the course of the project

The population growth rate for city of Jahrom, according to the public census of population and housing in 1390, was 1.1%. The shelf life of Jahrom's landfill has been considered equal 20 years. By using Eq.(1) the population of this city was calculated in several years. The results are presented in Table 3.

Quality and quantity of solid wastes

The weight evaluation of produced solid waste by citizens of Jahrom was started from September 2015 and was continued for one year using methods mentioned in material and methods section.

Table 2. Assumptions and parameter for using Screen View

Parameters	CO_2	CH_4	NMOCs
Emission rate	0.00067g/s.m^3	0.000491 g/s.m^3	0.0000072 g/s.m^3
Source release height was assumed equal of 0 m, receptor height above ground was assumed equal of 1 m, larger side of rectangular area was 980 m, smaller side of rectangular area was 280 m, dispersion coefficient was assumed as urban area and the source type was assumed to be area.			

Table 3. Population of Jahrom city in various years

Year	Population	Year	Population
2008	148400	2018	165556
2009	150032	2019	167377
2010	151682	2020	169218
2011	153351	2021	171079
2012	155038	2022	172961
2013	156743	2023	174864
2014	158467	2024	176787
2015	160210	2025	178732
2016	161973	2026	180698
2017	163754	2027	182686

Fig.1 presents the average weight of produced wastes by Jahromi citizens in several seasons. It is worth mentioning that the produced solid waste in Jahrom are collected by 25 trucks on a daily basis which contain 3700 kg of solid waste by average which are transferred to the landfill. According to the information in Fig.1, the average produced solid waste in Jahrom is 93610 kg/day. By dividing the average produced solid waste in Jahrom over the population of this city in year 1394, a capitation of 584 is retrieved. The United Nations Development Program purposed a capitation of 500 to 900 g/day as the rate of waste production for citizens in third world countries [18]. The obtained capitation for the city of Jahrom also lies in the same range. In this study the density of the solid wastes in Jahrom during the course of several seasons was calculated at 310.42 to 316.38 kg/m^3 which is equivalent to 313.35 kg/m^3 on average.

By considering the estimated population of Jahrom during the course of several years and the clarity of solid waste production capitation, the weight of the produced solid waste for each year was calculated which is illustrated in Table 4.

The analysis results of the produced solid waste in Jahrom are presented in Fig.2. As it is illustrated, 69% of composed mass from solid wastes belong to organic perishable compounds which is capable of producing carbon dioxide, methane, hydrogen sulfide and other non-methane organic compounds under anaerobic conditions. Also, the percentage of other materials including plastic, glass, metals, textiles etc. are presented in Fig.2.

Table 4. Solid waste weight and generation per capital between 2008 and 2027

Year	Population	Waste generation (kg/d)	Year	Population	Waste generation (kg/d)
2008	148400	86666	2018	165555	96684.1
2009	150032	87619	2019	167376	97747.5
2010	151682	88582	2020	169217	98822.7
2011	153351	89557	2021	171079	99910.1
2012	155038	90542	2022	172960	101008.6
2013	156743	91538	2023	174863	102119.9
2014	158467	92545	2024	176786	103243.0
2015	160210	93610	2025	178731	104378.9
2016	161973	94592	2026	180697	105527.0
2017	163754	95632	2027	182685	106688.0

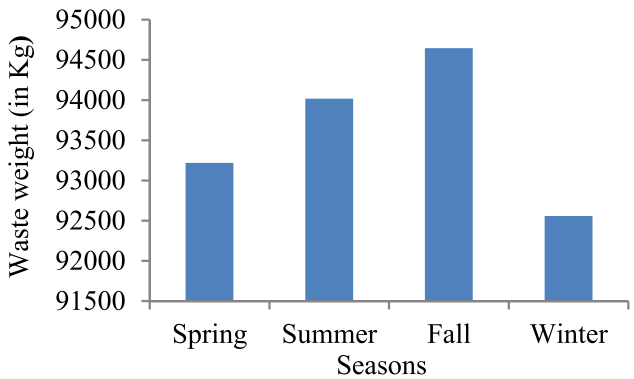

Fig.1. Amount of produced sold waste in Jahrom during various seasons

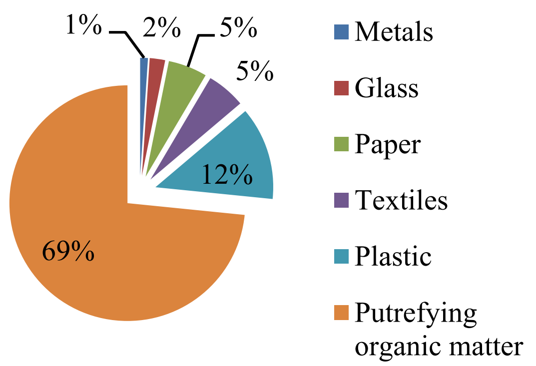

Fig.2. Solid waste analysis of Jahrom city

Local, climatic and geological information of landfill

The landfill of Jahrom is located in 15 km away from the city and it is adjacent to Jahrom-Bandar Abass road. This region owns 280 m in width and 980 m in height with an area of 274400 m^2. According to the surveys, the average of precipitation in Jahrom in the course of 33 years from 1337 to 1370 was equal to 230 mm and according to available data, the precipitation rate from 1370 to 1379 was equal to 204 mm. Geologically, the soil gradation is in optimum conditions due to the existence of conglomerate stones, sandstones and chiles and possess inappropriate penetration rate due to the existence of mostly clay soils which renders the underlying layers as Impervious. The surface of underground waters in this region is about 40 m and it is in inappropriate condition for formation of rocky aquifers and alluvial. This could be the reason behind the absence of ponds. The type of the land filling system is trench with a width of 8 m and height of 650 m and depth of 9 m. Also, about 800 m of access roads is established with a width of 6 m inside the landfill. 3400 m of fence is also constructed around the landfill. It is worth mentioning that according to the purposed method by a survey [18]. The Oleckno index was calculated based on the field conditions of landfill of Jahrom [19]. The calculation results showed that the Oleckno index for the disposal site is 41. Since the Oleckno index lies in the range of 24 and 42, the landfill of Jahrom is a suitable place for solid waste landfilling.

The calculation of produced gas

Overall emission of produced gasses and methane

Although, the optimum shelf life of landfills is between 20 to 40 years, however even after the end of operation, the landfill would still continue to generate pollutant gasses. The study results in Fig.3 shows that in the year 2027, the shelf life of Jahrom's landfill would end while continuing to generate pollutant gasses until 2148, in smaller quantities. According to the Fig.3, the ratio of produced methane in landfill would increase with extended amounts of solid waste. Although after a short interval from the operation period in 2027, the ratio of produced methane would fall. The climax of methane production was 10570000 m^3 in year 2028 which is one year after the end of landfill operation. According to Fig.3 the ratio of emitted methane in 2148 would be 26190 m^3. The reason behind this fall after the end of operation is the depletion of perishable organic mass due to the biochemical decomposition.

According to Fig.3 the ratio of produced biogas in the landfill is increase with the rise of produced waste which would also experience a fall in 2027 with the end of the landfill operation. The climax of produced biogas is observed in 2028 which is equal to 21130000 m^3/year. Since methane is the most important factor in global warming, the collection and employment of these gasses could lead to a fall in severity of global warming. It is worth mentioning that methane is lighter than the air and would move towards the earth surface. The risk of sudden fires also increases when the concentration of methane on ground surface reaches the range of 5 to 15% which pose a grave danger for the installments of the landfill [17]. Methane is highly flammable and releases ample energy while it burns. Therefore extraction and consumption of this gas can recycle energy which is much financially beneficial. According to previous studies report, every cubic meter of methane has the energy potential of 0.00165 MW [16]. Thus, extraction and consumption of the produced methane in Jahrom landfill can recycle 8375 MW of energy by 2016. The methane energy production potential in landfill of Jahrom between the years of 2008 and 2148 is represented in Fig.4. According to Fig.4, the highest level of energy generation potential is observed in the year 2028 with 18440 MW of energy being recycled in the landfill.

Based on the research conducted in El Salvador and the ratio of methane generation in the landfill of this city, the annual solid waste generation between 175000 and 262000 tons was variable in the range of 380 and 3680 m^3/h. Due to different climatic condition and precipitation rates and the variable ratios of disposed waste, running a comparison between the two cities is not easily possible. It should be noted that the estimation of gases produced from Jahrom's landfill after 2030 may not so accurate.

According to a survey for every megawatts of electricity generated in gas power plants, 54.88 tons of carbon dioxide is released into the atmosphere [20]. Therefore the potential to reduce the amount of carbon dioxide discharged by recycling methane could be calculated. The results of this calculation are presented in Fig.4. According to Fig.4, in case of recycling the methane obtained from the disposal sites of Jahrom, by year 2028 which is the climax of methane generation, 957100 ton of carbon dioxide is prevented from entering the atmosphere. Therefore recycling methane can have a direct and indirect effect on the quality of the atmosphere in Jahrom and nearby regions.

The emission ratio of carbon dioxide

Every day, million tons of solid organic perishable wastes are disposed and hundred million tons of carbon dioxide is released into the atmosphere through biological decomposition. At it is illustrated in Fig.5, by increasing the volume of waste disposed in Jahrom, the volume of carbon dioxide is also increased. The climax of carbon dioxide generation is calculated at 10570000 m^3

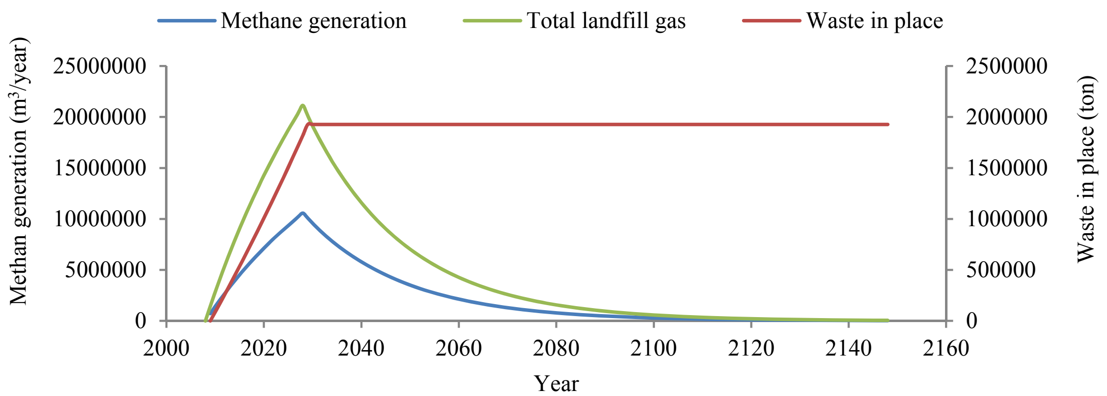

Fig.3. Methane generation and solid waste in place between 2008 and 2148

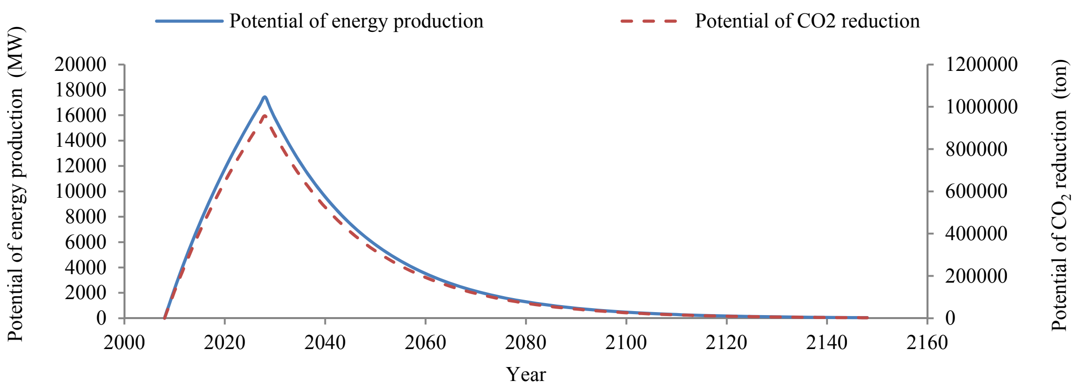

Fig.4. Potential of energy production and carbon dioxide reduction from recovered methane

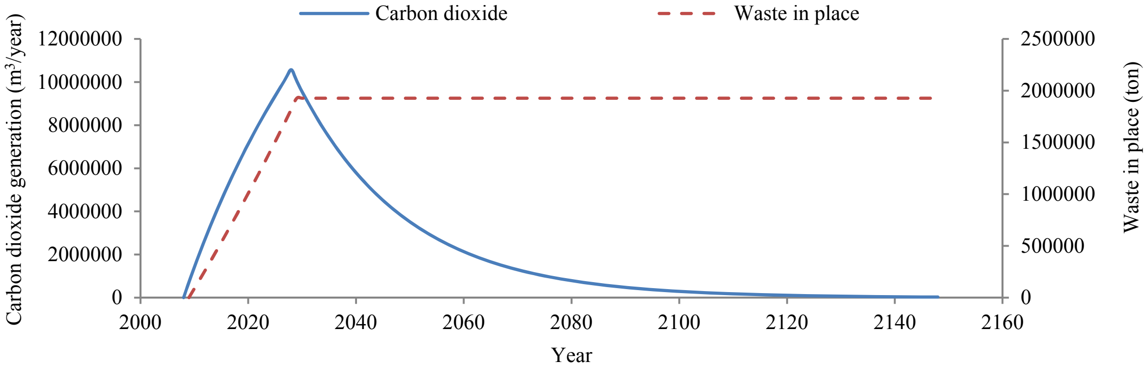

Fig.5. Carbon dioxide generation between 2008 and 2148

by the year 2028. Although, the generation of carbon dioxide is significantly reduced after the end of disposal operation, the generation carbon dioxide continues for several years. It estimated that by the year 2148, 26190 m^3 of carbon dioxide is released into the atmosphere from the landfill. It was reported in a survey that in the year 2011, United States of Americas has faced 12 climatic tragedies which caused 1 billion dollar of losses [21]. According to researchers these tragedies were as the result of global warming and climatic change. Therefore, controlling the global warming by reducing the volume of greenhouse gasses especially carbon dioxide is highly important. There are various methods purposed for the elimination of carbon dioxide all of which are very expensive. Therefore the best control method is reducing the generation of carbon dioxide [22]. The strict application of waste recycling programs can prevent the waste disposal through landfilling which would lead to less carbon dioxide. According to the reports of various researchers, recycling the solid waste can not only eliminate the environmental risks but also create more job opportunities and compensate portions of solid waste collection costs. Currently the cost for every ton of liquid carbon dioxide is 12 dollars in the market. Considering that in the climax of carbon dioxide generation by 2028, 1900 ton of carbon dioxide is generated which it is valued at 230000 dollars in case of recycling and purification. However, there are easier and more economical methods to produce carbon dioxide which would eliminate the need for gasses extracted at the landfill.

The emission ratio of non-methane organic gasses

The non-methane organic compounds are a series of chemical compounds with different chemical structure but similar behavior in the atmosphere. The non-methane organic compounds enter the atmosphere by means of burning, solvents and production processes. Non-methane organic compounds can lead to the formation of tropospheric ozone which is harmful for human health. In addition benzene or 1.3 butadiene is also highly dangerous. Investigating all the non-methane organic compounds could act as an indicator for the total traumatic properties of these pollutants. Fig.6, represent the total produced non-methane organic compound between the years 2008 and 2148. The highest level of emission is observe in the year 2028 from the landfill of city of Jahrom. Although, in proportion to the amount of carbon dioxide released, non-methane organic compounds are inconsiderable, however even in low volume these pollutants are still very harmful for human health. The ratio of generation and emission of non-methane organic compounds are presented in Table 5.

Table 5. Amount of 46 gas pollutants emission produced in imaginary landfill of Najafabad in 2016 (estimated by LandGEM)

Gas / Pollutant	Emission Rate	
	(ton/year)	(m^3/year)
Total landfill gas	12680	10150000
Methane	3386	5076000
Carbon dioxide	9291	5076000
NMOC	145.6	40610
1,1,1-Trichloroethane (methyl chloroform) - HAP	0.027	4.873
1,1,2,2-Tetrachloroethane - HAP/VOC	0.078	11.170
1,1-Dichloroethane (ethylidene dichloride) - HAP/VOC	0.100	24.360
1,1-Dichloroethene (vinylidene chloride) - HAP/VOC	0.008	2.030
1,2-Dichloroethane (ethylene dichloride) - HAP/VOC	0.017	4.162
1,2-Dichloropropane (propylene dichloride) - HAP/VOC	0.009	1.827
2-Propanol (isopropyl alcohol) - VOC	1.269	507.600
Acetone	0.172	71.060
Acrylonitrile - HAP/VOC	0.141	63.960
Benzene - No or Unknown Co-disposal - HAP/VOC	0.063	19.290
Benzene - Co-disposal - HAP/VOC	0.363	111.700
Bromodichloromethane - VOC	0.214	31.470
Butane – VOC	0.123	50.760
Carbon disulfide - HAP/VOC	0.019	5.888
Carbon monoxide	1.656	1421.000
Carbon tetrachloride - HAP/VOC	0.000	0.041
Carbonyl sulfide - HAP/VOC	0.012	4.974
Chlorobenzene - HAP/VOC	0.012	2.538
Chlorodifluoromethane	0.047	13.200
Chloroethane (ethyl chloride) - HAP/VOC	0.035	13.200
Chloroform - HAP/VOC	0.002	0.305
Chloromethane - VOC	0.026	12.180
Dichlorobenzene - (HAP for para isomer/VOC)	0.013	2.132
Dichlorodifluoromethane	0.817	162.400
Dichlorofluoromethane - VOC	0.113	26.390
Dichloromethane (methylene chloride) - HAP	0.502	142.100
Dimethyl sulfide (methyl sulfide) - VOC	0.205	79.180
Ethane	11.300	9035.000
Ethanol – VOC	0.525	274.100
Ethyl mercaptan (ethanethiol) - VOC	0.060	23.350
Ethylbenzene - HAP/VOC	0.206	46.700
Ethylene dibromide - HAP/VOC	0.000	0.010
Fluorotrichloromethane - VOC	0.044	7.715
Hexane - HAP/VOC	0.240	67.000
Hydrogen sulfide	0.518	365.500
Mercury (total) - HAP	0.000	0.003
Methyl ethyl ketone - HAP/VOC	0.216	72.080
Methyl isobutyl ketone - HAP/VOC	0.080	19.290
Methyl mercaptan - VOC	0.051	25.380
Pentane - VOC	0.101	33.500
Perchloroethylene (tetrachloroethylene) - HAP	0.259	37.560
Propane - VOC	0.205	111.700

Table 5. Amount of 46 gas pollutants emission produced in imaginary landfill of Najafabad in 2016 (estimated by LandGEM)

Gas / Pollutant	Emission Rate (ton/year)	Emission Rate (m^3/year)
t-1,2-Dichloroethene - VOC	0.115	28.430
Toluene - No or Unknown Co-disposal - HAP/VOC	1.517	395.900
Toluene - Co-disposal - HAP/VOC	6.613	1726.000
Trichloroethylene (trichloroethene) - HAP/VOC	0.155	28.430
Vinyl chloride - HAP/VOC	0.193	74.110
Xylenes - HAP/VOC	0.538	121.800

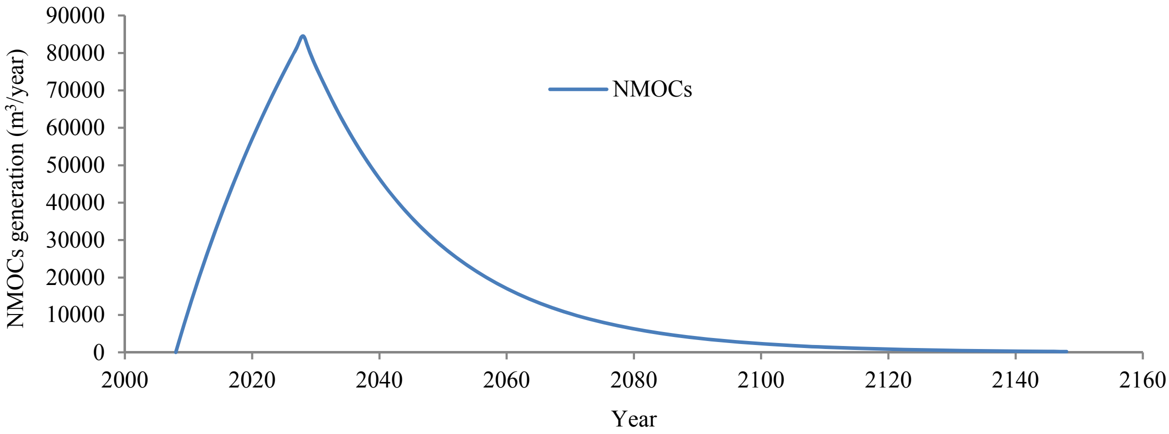

Fig.6. NMOCs generation between 2008 and 2148

The modeling of the pollutants emission into the atmosphere

In this study, the emission of pollutant gasses from the Jahrom disposal sites are modeled using the Screen View. In the first step the average of generated pollutants were calculated using Figs.3, 5 and 6. The average for the generated carbon dioxide, methane and non-methane organic compounds were respectively 135, 184, 2 g/s. By dividing the average emission ratio of these pollutants over the area of landfill, the ratio of emission from every square meter was calculated over the time unit in which for carbon dioxide, methane and non-methane organic compounds were respectively 0.00067, 0.000491 and 0.0000072 g/s.m^2.

The results of the modeling for the emission ratio of mentioned pollutants are presented in Fig.7. It is worth mentioning that the concentration of pollutants presented in Fig.7 is simply in the direction of the wind. The result illustrate that by taking distance from the landfill, the concentration of pollutants in atmosphere fall dramatically however even at the distance of 15000 away from the disposal site the concentration of pollutants would still be measurable. Since the average of carbon dioxide in atmosphere is 0.00756 g/m^3, the concentration of carbon dioxide from a distance of 100 m away from the disposal site would be about 0.06 g/m^3. By taking distance, up to 500 m away, the concentration of carbon dioxide would reach its climax which would be 0.073 g/m^3. According to the Fig.7, the concentration of carbon dioxide falls to 0.00956 g/m^3 by tak-

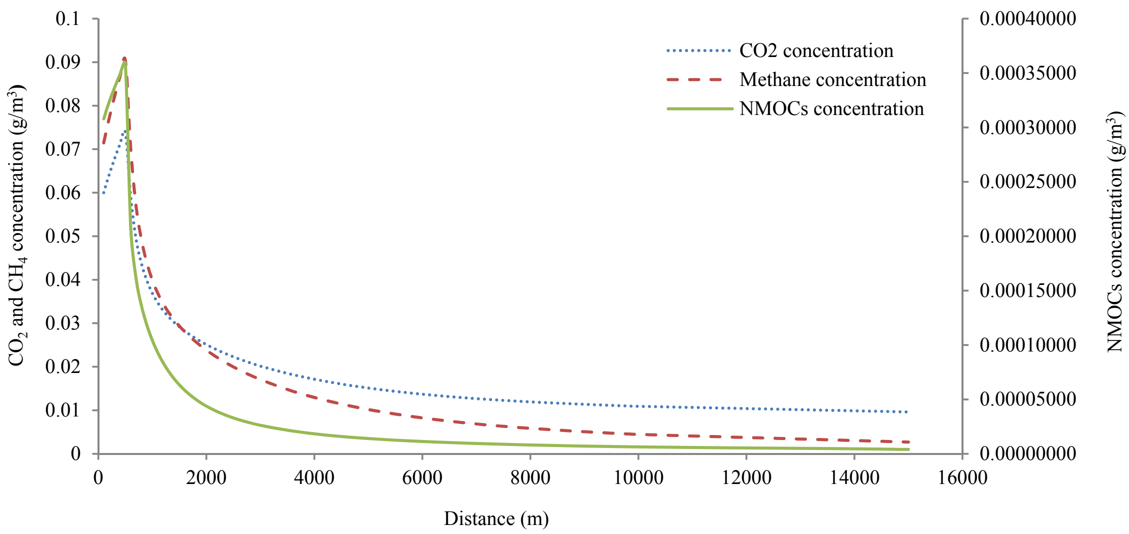

Fig.7. Relationship between CO_2, CH_4 and NMOCs concentration and distance in the wind direction

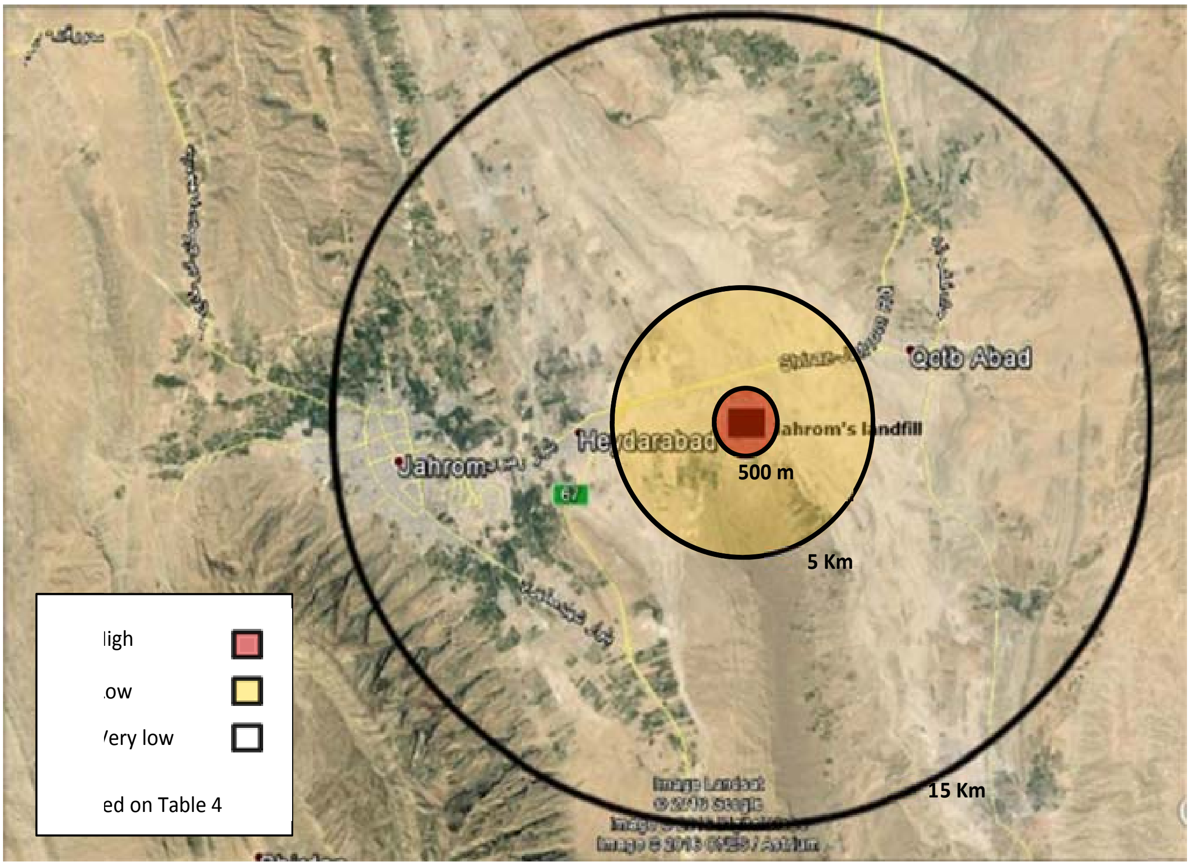

Fig.8. Radius emissions of landfill's pollutants based on Table 4

Table 6. Range of pollutants concentration in different distances from landfill

Pollutants	Range (g/m^3)	Distance from landfill (m)	Definition
Carbon dioxide	5.2×10^{-2} to 6.6×10^{-2}	100-500	High
	6.6×10^{-2} to 7×10^{-3}	500-5000	Low
	7×10^{-3} to 1×10^{-3}	5000-15000	Very low
Methane	7.1×10^{-2} to 9×10^{-2}	100-500	High
	9×10^{-2} to 1×10^{-2}	500-5000	Low
	1×10^{-3} to 2×10^{-3}	5000-15000	Very low
NMOCs	3×10^{-4} to 4×10^{-4}	100-500	High
	4×10^{-4} to 4×10^{-5}	500-5000	Low
	1×10^{-5} to 4×10^{-7}	5000-15000	Very low

ing a distance of 15000 m away from the landfill. Similar conditions are also observed for methane and non-methane organic compounds. The concentration of methane and non-methane organic compounds reaches 0.0026 and 0.0000004 g/m^3 at a distance of 15000 m away from the landfill. Since the distance of landfill from the city is 15000 m, thus in case of wind blow in the proper direction, inconsiderable amounts of pollutants generated at landfill can reach towns' atmosphere and contaminate it. The concentrations of pollutants are schematically presented in Fig. 8 based on data from Table 6.

CONCLUSIONS

Our study results suggests that the ratio of methane generation at the landfill of Jahrom over the course of 140 years after the establishment would be variable in the range of 26190 and 10180000 m^3/year. Currently no biogas collection system is employed in the Jahrom solid waste landfill which has led to the emission of 4684000 m^3/year of methane and carbon dioxide into the atmosphere. The rate of methane and carbon dioxide generation for each person is calculated equal of 28.91 m^3/year for 2016. The average density of the solid wastes collected in the city of Jahrom was 313.35 kg/m^3 and the capitation of the solid wastes generated by the Jahromi citizens was 584 g/d. It was also revealed that in case of wind blow in the proper direction, inconsiderable amounts of pollutants can be transferred from the landfill to the city. The results obtained from this study can be used in the energy planning of Jahrom's landfill and also determining the share of Iran in the global generation of greenhouse gasses. Moreover, by considering the ratio of methane generated, the gas extraction system could be personalized for every individual landfill which not only grants the opportunity to take advantage of the gasses produced but also prevent tragedies related to fires and explosions.

FINANCIAL SUPPORTS

Islamic Azad University branch of Bushehr and Jami Institute of Technology financially supported this study (Vot. 000106).

ACKNOWLEDGEMENTS

This article has been written from a dissertation in field of environmental engineering at Jami Institute of Technology, Isfahan, Iran. The authors of this article appreciate Jami Institute of Technology for its financial and moral support, which led to the completion of this dissertation.

COMPETING INTERESTS

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

ETHICAL CONSIDERATIONS

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

REFERENCES

[1] Tchobanoglous G, Theisen H, Vigil S. Integrated solid waste management: engineering principles and management issues. McGraw-Hill, Inc.; 1993.

[2] U.S. Department of Energy. Greenhouse gases. Landfill technology. Butterworth Scientific Ltd. DO; 1995.

[3] EPA. 1995. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emissions Factors, AP-42, Fifth Addition, Volume 1: Stationary Point and Area Sources. January 1995. [Internet]. 2016 [cited 31 July 2016]. Available from: http://www.epa.gov/ttn/chief/ap42/ch02/Section.

[4] US Department of Health and Human Services. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Asbestos. Update; 1999.

[5] Solid Waste Association of North America. Landfill Gas Operation and aintenance Manual of Operation. 1997. [Internet]. 2016 [cited 31 July 2016]. Available from: http://www.osti.gov/bridge/product.biblio.jsp?osti_id=314156.

[6] Landfill Gas Basics [Internet]. Agency for Toxic Substances and Disease Registry. 2016 [cited 31 July 2016]. Available from: http://www.atsdr.cdc.gov/HAC/landfill/html/ch2.html.

[7] Environmental Protection Agency. Organic air emissions from waste management facilities. Washington: Environmental Protection Agency; 1992.

[8] Roshan A, Talaiekhozani A, Roodpeyma Sh. A Review on Removal of Pollutants from Air Using Biological Methods. The 5th Conference on Application of Chemistry in Novel Technology. Isfahan: Jami Institute of Technology; 2015.

[9] Watzinger A, Reichenauer TG, Blum WE, Gerzabek MH, Zechmeister-Boltenstern S. The effect of landfill leachate irrigation on soil gas composition: methane oxidation and nitrous oxide formation. Water, air, and soil pollution. 2005 Jun 1;164(1-4):295-313.

[10] Haubrichs R, Widmann R. Evaluation of aerated biofilter systems for microbial methane oxidation of poor landfill gas. Waste Management. 2006 ; 26(4):408-16.

[11] Talaiekhozani A. Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide [internet]. Talaiekhozani; 2015 [updated 2015 Oct 18; cited 2016 January 8] Available from Netlibrary: http://www.researchgate.net/publication/282943665_3.02_.

[12] Talaiekhozani A, Bagheri M, Najafabadi NR, Borna E. Effect of nearly one hundred percent of municipal solid waste recycling in najafabad city on improving of its air quality. Journal of Air Pollution and Health. 2016;1(2):111-22.

[13] Omrani GhA, Mohseni N, Haghighat K, Javid A.H. Technical and Sanitary assessment of Methane extraction from Shiraz Landfill. Journal of Environmental Science and Technology. 2009 Jun 1; 10(4):175–182.

[14] Safari E, Asadollahfardi GhR, Joghtaee F. Evaluation of reducing possibility of produced methane pollution in municipal landfill based on sustainable development mechanism in Rasht city. 4th National Congress on Waste Management, Mashhad: Municipalities and state agencies; 2010.

[15] Safari E. Reduction of Produced Methane Gas from Landfill by Applying Clean Development Mechanism (Case Study: Mashhad Landfill) [M.Sc]. Tehran University; 2012.

[16] Pazoki M, Delarestaghi RM, Rezvanian MR, Ghasemzade R, Dalaei P. Gas Production Potential in the Landfill of Tehran by Landfill Methane Outreach Program. Jundishapur Journal of Health Sciences. 2015;7(4).

[17] Jonidi Jafari A, Talaiekhozani A. Introduction to Solid Waste Management. Tehran: Ebadifar Publisher; 2011.

[18] Sanphoti N, Towprayoon S, Chaiprasert P, Nopharatana A. The effects of leachate recirculation with supplemental water addition on methane production and waste decomposition in a simulated tropical landfill. Journal of Environmental Management. 2006;81(1):27-35.

[19] Dehghani M, Abjadian MH, Zamanian Z. Study the appropriateness of the Shiraz sanitary solid waste landfill site with OLECKANO index. 1th National Congress on Waste Management, Mashhad: Municipalities and state agencies; April 21, 2012.

[20] DeLuchi MA. Emissions of greenhouse gases from the use of transportation fuels and electricity. Volume 1, Main Text. Argonne National Lab., IL (United States). Energy Systems Div.; 1991.

[21] Mohajan HK. Greenhouse Gas Emissions of China. Journal of Environmental Treatment Techniques. 2014;1(4):190-202.

[22] Talaiekhozani A, Masomi B, Hashemi SM. Evaluation of Gaseous Pollutants Emission Rate from Marvdasht Landfills. Journal of Advanced Medical Sciences and Applied Technologies. 2016 ;2(1):162-75.