Estimation of Methane gas Emission from Solid Waste disposal sites in Kano, Nigeria

Lawal Abdu Daura, Prof. Joseph Enaburekhan, Dr. I. A. Rufai

Abstract— Estimation of methane gas emission from four municipal solid waste dumpsites in Kano, Nigeria was carried out. The amount of methane gas emissions from the four dumpsites from the year 2012- 2040 were predicted using LandGEM landfill gas emission model. The maximum methane emission from Court road dumpsite is 4.655E+05 m^3/year which would be generated in the year 2016 and would decline to 1.786E+05 m^3/year by the year 2040. The maximum methane emission from Hajj Camp dumpsite is 2.995E+05 m^3/year which is expected to be generated in the year 2018 and would decline to 1.215E+05 m^3/year by the year 2040. The maximum methane emission from Maimalari dumpsite is 4.197E+05 m^3/year which would be generated in the year 2024 and would decline to 2.206E+05 m^3/year in 2040, while for Ubagama dumpsite the maximum emission is 6.014E+04 m^3/year which would be generated in the year 2040 and the minimum is 3.053E+04 m^3/year in the year 2012.

Index Terms— Estimation, Emission, Landfill gas, Methane

1 Introduction

Anaerobic reaction within solid waste disposal sites generates various gases (landfill gas) mainly methane and carbon dioxide. In addition other non methane volatile organic compounds are also produced [1], [2]. The exact percentage distribution of gases in landfill varies, but typical constitutions found in municipal solid waste disposal sites are methane 45 - 60 % , carbon dioxide 40 – 60% [3],[4]. According to Intergovernmental Panel on Climate Change [1], the gases produced in solid waste disposal sites, particularly methane, can be a local environmental hazard if precaution are not taken to prevent uncontrolled emissions or migration into surrounding lands. Landfill gas is produced both in landfills (properly managed solid waste disposal sites) and open dumps (unmanaged waste disposal sites) and are both considered solid waste disposal sites [1]. Both of the two primary constituents of the landfill gas (methane and carbon dioxide) are considered green house gases, which contribute to global warming, but IPCC does not consider carbon dioxide present in raw landfill gas to be a green house gas(GHG) because it consider landfill gas carbon dioxide as biogenic and thus part of the carbon cycle, therefore only the methane content in landfill gas is considered as GHG. Methane is more potent green house gas than carbon dioxide, with global potential of over 21 times that of carbon dioxide [5], [6]. Solid waste disposal sites which remain the primary waste disposal strategy [7] comprises the principal sources of anthropogenic methane emissions, and are estimated to account for 5 – 20% of anthropogenic methane emissions globally [1]. The atmospheric concentration of methane has increased by 151% since 1750 and its concentration continues to increase [8]. Globally efforts are being made to control green house gas emission from various sources, waste sector inclusive. In this study methane gas emissions from four major dumpsites in Kano were estimated using LandGEM landfill gas emission model.

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2 Materials and Methods

The four dumpsites namely, Court road, Maimalari, Hajj camp and Ubagama are located within Kano municipality.

2.1 Waste characterization/ physical composition

Characterization of waste at the disposal sites were carried out according to the American Society for Testing and Materials (ASTM D5231) [9]. The procedure involved random collection of waste from trucks loads in the amount of 15 to 20kg per unit. About 100 kg sample of solid waste was collected per day in each of the four dumpsites. At each dumpsite the collected sample waste was then spread on a polythene sheet and sorted into different categories of plastics, paper, textile material, glass, vegetable /Agricultural waste, metal and earth/ decayed matter. The categorized wastes were then weighted using a weighting scale and their percentage weight recorded. This procedure was conducted in the months of October, March and August (2012-2013) to cater for seasonal variations.

2.2 Dumpsites capacity

The years of opening of the dumpsites (t) were obtained from Kano State Refuse management and sanitation Board (REMASAB). As the dumpsites have not reached their full capacity, the expected year of closure of the dumpsites are determined based on the capacity and rate of waste disposal at the dumpsites. The capacity of the waste dumps were determined based on waste dump area, average depth and density

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of the waste. The dumpsites areas were obtained using Google Map and Esri Arcgis softwar program (Google Map, 2013, ArcGIS, 2003). Satellite image of the dumpsites were obtained and the area determined using the program. Record of average depths of the dumpsites and estimated amount of waste in the dumpsites as of 2012 were obtained from REMASAB. The density of waste were determined by placing the samples of waste collected in a 250 ml beaker, shaking and slightly dropping and then weighting. The waste density is then calculated by dividing the weight of the waste by its volume [10].

2.3 Methane generation potential of the solid waste disposal sites

Methane generation from the solid waste dumpsites were estimated using the LandGEM equation:

$$Q_{CH4}=\sum_{i=1}^{n}\sum_{j=0.1}^{1} kL_o \left|\frac{M_i}{10}\right| \left(e^{-kt_{ij}}\right) \quad (1)$$

Where:

Q_{CH4} = Annual methane generation in the year of calculation (m^3 yr-1)

i = The yearly time increment

n = Difference : (year of the calculation) – (initial year of waste acceptance)

j = 0.1 year increment

L0 = Methane generation potential (m^3/Mg)

Mi= Mass of waste accepted in the ith year (Mg)

k = Methane generation rate (yr-1)

tij = Age of jth section of waste mass Mi accepted in the ith year.

The important parameters of the LandGEM equation for the generation of methane gas are Lo (methane generation potential) and k (methane generation rate).

2.31 Methane generation potential (L_O)

The methane generation potential is determined from the equation(IPCC,1996);

$$L_0 = DOC \times DOC_f \times F \times {}^{16}/_{12} \times MCF \quad (2)$$

$$DOC = (0.4 \times A) + (0.17 \times B) + (0.15 \times C) + (0.3 \times D) \quad (3)$$

Where:

DOC = degradable organic carbon

A= fraction of MSW that is paper and textiles wastes, B = fraction of MSW that is garden park waste, C= fraction of MSW that is food waste and D= fraction of MSW that is wood or straw.

DOCf = fraction of assimilated degradable organic carbon(DOC)is obtained from the IPCC default value of 0.77 (IPCC, 1996).

MCF = Methane correction factor. This is based on the category of the solid waste disposal site (SWDS)

management as presented by IPCC:

Managed sites MCF = 1.0

Unmanaged, deep sites (≥ 5m) MCF = 0.8

Unmanaged, shallow sites (< 5m) MCF = 0.4

Unspecified SWDS - default value: MCF = 0.6

F = fraction of methane in landfill gas (0.5 default)

16/12 = stoichiometric factor.

2.32 Methane generation rate constant

The methane generation rate constant or decay rate k, is determined based on US EPA(2004);

$$k = 3.2 \times 10^{-5}(x) + 0.01 \quad (4)$$

Where x is annual average precipitation.

3 Results and Discussions

3.1 Waste composition

The result of the composition analysis of the solid waste at the four dumpsites conducted in the months of October, March and August (2012-2013) are shown in table 1.

Table1: Average% of waste composition

Category	Court road	Maiamalari	Hajj camp	Ubagama
Plastics	27.88	28.34	29.14	29.22
Paper	7.60	4.70	12.68	8.31
Textiles	11.48	5.13	8.41	10.18
Glass	1.87	3.63	1.57	2.94
Agricultural	21.78	15.54	18.69	17.58
Earth/ garbage	21.65	34.27	28.20	30.97
Metals	0.19	0.06	0.00	0.12
Food waste	7.49	8.33	1.32	0.67

3.2 Dumpsites capacity

The capacities of the waste dumps were determined based on waste dump area, average depth and density of the waste. The dumpsites areas were obtained using Google Map and Esri Arcgis software program (Google Map, 2013, ArcGIS, 2003). Satellite image of the dumpsites were obtained and the area determined using the program. Table 2 shows the density of the solid waste in the dumpsites, average depth and areas of the dumpsites.

Table 2: Dumpsites densities and areas

Dumpsites	Waste density (kg,m^3)	Average depth (m)	Area (m^2)
Court road	276.00	20.00	43,337.93
Hajj Camp	321.60	10.00	41,855.16
Maimalari	255.00	13.50	92,832.31
Ubagama	234.00	8.00	28,867.84

The density of the solid waste from the four dumpsites varies from 321.60 kg/m^3 – 234.00 kg/m^3, while average depth and area of the dumpsites ranges from 20.0m - 8.00m and 92,832.31 m^2 – 28,867.84m^2 respectively. Table 3 shows the estimated capacities of the four dumpsites.

Table 3: Estimated capacitiesof the dumpsites

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Dumpsite	Estimated capacity (m^2)	Estimated capacity (tons)
Court road	866,788.60	239,233.65
Hajj camp	418,551.60	134,606.20
Maimalari	1,253,236.19	319,575.23
Ubagama	230,942.72	54,040.60

The amounts of waste in place as of year 2012 in the four dumpsites are shown in table 4.

Table 4: Waste in place as of year 2012

Dumpsite	Initial year of waste disposal (year)	Waste in place as of 2012 (Mg)	Average annual waste disposal (Mg/year)
Court Road	1991	188,304.60	9415.23
Hajj Camp	2003	72,203.40	9025.43
Maimalari	2003	120,395.29	15049.41
Ubagama	1999	13,693.38	1,141.12

3.4 Methane generation

The important parameters in the LandGEM equation (1), methane generation potential (L_O) and methane generation rate constant (k) were computed from equation (2) and (4) respectively.

The DOC values of the waste in the four dumpsites were computed using the waste compositions in table 1.

DOCf = fraction of assimilated degradable organic carbon(DOC)is obtained from the IPCC default value of 0.77 (IPCC, 1996). As all the four dumpsites fall within the category of unmanaged , deep dumpsites (≥ 5m, from table 2) their MCF value is therefore 0.8. Default value of 0.5 (IPCC, 1996) for fraction of methane in the landfills is assigned.

The methane generation rate or decay rate k, is determined using the annual average precipitation of Kano which has the value of 873mm (Kano climate, kano.gov.ng,). Table 5 shows the computed parameters

Table 5: Methane generation potential

Dumpsite	k (y^{-1})	L_o (m^3/Mg)
Court road	0.041	76.94
Hajj Camp	0.041	48.01
Maimalari	0.041	72.63
Ubagama	0.041	64.63

The LandGEM landfill gas equation model was run using the computed parameters and the result is shown in table 6.

From the result, table 6 show the annual methane emission from the four municipal solid waste dumpsites in Kano. The maximum methane emission from Court road dumpsite is 4.655E+05 m^3/year which would be generated in the year 2016 and would decline to 1.786E+05 m^3/year by the year 2040. The maximum methane emission from Hajj Camp dumpsite is 2.995E+05 m^3/year which is expected to be generated in the year 2018 and would decline to 1.215E+05 m^3/year by the year 2040. The maximum methane emission from Maimalari dumpsite is 4.197E+05 m^3/year which would be generated in the year 2024 and would decline to 2.206E+05 m^3/year in 2040, while for Ubagama dumpsite the maximum emission is 6.014E+04 m^3/year which would be generated in the year 2040 and the minimum is 3.053E+04 m^3/year in the year 2012.

Table 6: Annual methane emission (2012-2040)

YEAR	METHANE GENERATION (m^3/yr) Court Road	Hajj camp	Maimalari	Ubagama
2012	4.191E+05	2.027E+05	2.234E+05	3.053E+04
2013	4.314E+05	2.209E+05	2.435E+05	3.227E+04
2014	4.432E+05	2.385E+05	2.628E+05	3.394E+04
2015	4.546E+05	2.553E+05	2.814E+05	3.555E+04
2016	4.655E+05	2.714E+05	2.991E+05	3.709E+04
2017	4.587E+05	2.869E+05	3.162E+05	3.857E+04
2018	4.403E+05	2.995E+05	3.326E+05	3.999E+04
2019	4.226E+05	2.875E+05	3.483E+05	4.135E+04
2020	4.056E+05	2.759E+05	3.634E+05	4.266E+04
2021	3.893E+05	2.648E+05	3.779E+05	4.391E+04
2022	3.737E+05	2.542E+05	3.918E+05	4.512E+04
2023	3.587E+05	2.440E+05	4.051E+05	4.627E+04
2024	3.443E+05	2.342E+05	4.179E+05	4.738E+04
2025	3.304E+05	2.248E+05	4.080E+05	4.845E+04
2026	3.172E+05	2.157E+05	3.916E+05	4.947E+04
2027	3.044E+05	2.071E+05	3.759E+05	5.045E+04
2028	2.992E+05	1.988E+05	3.608E+05	5.139E+04
2029	2.805E+05	1.908E+05	3.463E+05	5.230E+04

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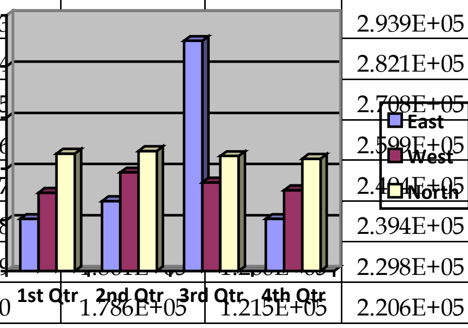
2030	2.692E+05	1.831E+05	3.324E+05	5.316E+04
2031	2.584E+05	1.757E+05	3.190E+05	5.400E+04
2032	2.480E+05	1.687E+05	3.062E+05	5.480E+04
2033	[illegible]	[illegible]	2.939E+05	5.556E+04
2034	[illegible]	[illegible]	2.821E+05	5.630E+04
2035	[illegible]	[illegible]	2.708E+05	5.701E+04
2036	[illegible]	[illegible]	2.599E+05	5.768E+04
2037	[illegible]	[illegible]	[illegible]	5.834E+04
2038	[illegible]	[illegible]	2.394E+05	5.896E+04
2039	[illegible]	[illegible]	2.298E+05	5.956E+04
2040	1.786E+05	1.215E+05	2.206E+05	6.014E+04



4 Conclusion

The annual methane emission from the four municipal solid waste disposal sites in Kano had been estimated using the LandGEM landfill gas model. The results show that from the year 2012- 2040 Court road dumpsite would have the maximum methane emission of 4.655E+05 m^3/year which is expected to occur in the year 2016, while Ubagama dumpsite with maximum methane emission of 6.014E+04 m^3/year which would be observed in the year 2040 has the least methane emission amongst the four dumpsites.

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