GHGs emission from MSW dump site in Faridabad, India

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Abstract. **In developing countries like India, the amount of MSW is increasing continuously day by day and out of all the MSW management strategies, opens dumping and landfilling is most common method to manage the about 70-90%of MSW resulting release of GHGs in the atmosphere and causes global warming. The present paper represented that the estimation of GHG emission from the transportation sector and dumping site. Three methodologies are used to estimate the emission from the dumping site namely, IPCC Default method, First order Decay (FOD) and LandGEM 3.02 version. Annual average GHGs emission from the bandhwari landfill site is calculated as 5.40, 1.22 and 1.77 Gg using three methods and total GHGs emission from the transportation sector is calculated 733 TonneCO_2eq/year.**

The results of this study found that IPCC Default method gives higher value of emission while the FOD and LandGEM model gives almost similar results. Therefore, LandGEM is recommended over FOD due the simplicity in model parameters and avoidance of over estimation for GHG emission from MSW. Through, the recycling of material from the MSW, net reduction in GHGs is found as -6528.19 Tonne CO_2eq/Year .The overall GHGs emission from MSW management of Faridabad city is found as 31375 Tonne CO_2eq/Year. According to the waste composition of the MSW of Faridabad and the proximate analysis of the waste, the waste is found to have a power potential of 10 MW if the waste is properly managed and converted to energy.

Keywords: **Landfill site; Municipal solid Waste (MSW); Green House Gas (GHG) emission; Municipal Corporation of Faridabad (MCF); LandGEM;**

1. Introduction

Due to the migration of people from villages to cities, rapid increase in industrialization and population growth, thousands of tons of MSW is produced in India. As per an estimate, about 62 million tonnes of waste was generated annually in 2011 in the country. Of total MSW generation, about 75-80% of MSW is collected, out of which only 22-28% is processed and treated while the remaining is disposed off without any treatment at dumping sites. It is projected that the MSW generation will increase to 165 million tonnes and 436 million tonnes by 2031 and 2050 respectively. Due to the poor collection and inadequate treatment facilities can pose risk to the environment and public health [1]. In India, almost 70-80% of the MSW is disposed off in to open dumping/ landfilling and resulting in the emissions of GHGs by way of aerobic and anaerobic degradation of wastes. These GHGs like CO_2, CH_4, N_2O and some other gases enters in to the environment and increase the temperature of earth surface. The estimation of GHG potential of such MSW dump sites using various methods has attracted the attention of researchers for the purpose of assessing the Global warming impacts GHG gases and associated climate changes [2].

As a default method, Modified triangular model (MTM) and first order decay (FOD) model to estimate the potential of CH_4generation [3,4].It used the system dynamic modeling approach to quantify the CH_4 emission from MSW in Delhi and revealed that by using suitable treatment technologies and replacement of open dumping by sanitary landfills may reduce CH_4 emission significantly [5]. They compare the modified Shafizadeh model with the modified Dulong model. In Srilanka, MSW has the potential to produce 9.3 GJ energy/ tonne of wastes but only 75% could be converted to useful energy[6]. It used in-situ closed chamber method to estimate the GHGs from the Perungudi and Kodungaiyur landfill site of Chennai[7]. Biofilters are used for controlling odor emission from the composting of MSW and used Life cycle assessment methodology to assess its impact on global warming potential [8,9].GHG emission is calculated from Bhandewadi landfill site of Nagpur and Amravati disposal site using Stoichiometric approach [10].It studied the power generation potential of MSW of Haridwar city and evaluated cost of energy without and with CDM far cheaper than grid power [11].CH_4 emission from Ghazipur, Bhalsa and Okhlain Delhi is estimated using different methods and found in- situ methodology as the better method [12].Ecuador GHG Model (version 1.0) is used to calculate the energy potential of CH_4 generation of Gazipur, Okhla, Balswa (Delhi), Gorai, Deonar (Mumbai), Pirana (Ahmedabad), UrliDevachi (Pune), and Autonagar site (Hyderabad) [13]. It showed recycling as one of the processes with socio-economic and environmental benefits because one tonne of recyclable waste can reduce 3.91×10^3 kg CO_2[14].It quantified the CH_4 emission from landfill sites in India and found CH_4emission to vary from 12.94 to 58.41 in winter and from 82.69-293 mg/m^2/h in summer [15].IPCC 2006 guidelines are used to estimate the GHG emission from membrane bioreactor treatment(MBT), open dumping and sanitary landfilling without gas recovery [16].LandGEM(version 3.02)software is used to estimate of GHG emission potential of three landfill sites of Delhi and found LandGEM(Version 3.02) to give better results [17]. They used the life cycle assessment method to estimate GHGs emission from the landfill and found that Landfill gas (LFG) to energy project toreduce 1,639,450 tCO_2-eq during the 20-years project period, which is equal to 43% of CH4 generated throughout the life cycle [18].Life cycle methodology is used to determine the effect of landfill extension (LFE) and advanced incineration facility (AIF) on environment, ecosystem quality and human health in Hongkong [19]. The life cycle approach is used for current and future GHG emission from MSW in eThekwini municipality, South Africa [20].LandGEM(version 3.02)is applied to estimate GHG emission potential of landfill sites of MSW in 23 Indian metro cities and found Mumbai as the highest contributor of GHG emission while Visakhapatnam the least [21].They used the Waste to energy (WTE) technologies for quantitative assessment of the environment [22]. IPCC Default, FOD, and LandGEM models are used for the estimation of CH_4 from open dumping site of Kanpur and found the annual average CH_4 emission rates as 197.33, 24.27 and 25.14 Gg by IPCC Default method, FOD and LandGEM respectively for the period 2010-2030 and LandGEM is recommended over FOD method due to getting better result [23].

Based on the above, it is found that assessment of GHG emission potential of MSW dump sites is being increasingly undertaken to know the extent of pollution affecting the health of human ecosystem. This will help to develop and utilize more and more technologies to recycle and produce energy from the wastes including composting**.** The present study deals with the assessment of MSW of Faridabad city, Haryana using various approaches and reports the results of GHG emission potential of dump site and recommended the suitability of assessment approach. The GHG estimation of Integrated MSW management is also reported along with suggestive measures.

2. Methodology Adopted

The three models viz IPCC Default Method, First order Decay (FOD) and LandGEM 3.02 version were applied on Bandhwari dumping site, Faridabad to estimate the GHG emission potential. Based on [23], IPCC default method is based on mass balance equation which is recommended by IPCC (2006) while the First order decay model followed the first order kinetics as a result in starting year GHG emission is highest but then gradually decline when microorganism present in MSW consume the degradable organic carbon and LandGEM 3.02 version based on first order rates equation used to estimate rates for CH_4, CO_2, biogas, NMOCs & individual air pollutant from MSW Landfills. Proximate analysis of MSW samples was done using standard methods of analysis. The samples were collected from the site, analyzed and finally represented in terms of biodegradable and non-biodegradable wastes.

2.1 MSW Management in Faridabad (Haryana)

The population of Faridabad is 15.50 million with the generation of 631 TPD MSW. The city is divided in 3 zones i.e NIT Faridabad, Old Faridabad, and Ballabgarh. MSW in Faridabad is managed by 8 NGOs. The main features of Faridabad city is given in table 1 and site location in Fig 1.

Table 1. Main Features of Faridabad City

Sr. No.	Features		Faridabad	
		Zone – 1 [NIT Faridabad]	**Zone -2 [Old Faridabad Zone]**	**Zone -3 [Ballabgarh Zone]**
1	No. of Wards	19	9	7
2	Total Area (Km^2)	135.9	42.11	28.87
3	Population(2016)	837549	420653	321288
4	Quantity of Waste(Gg/year)	122	61	47
5	Means of Collection	• Door to Door • Street Sweeping	• Door to Door • Street Sweeping	• Door to Door • Street Sweeping
6	Total No. of Vehicles used	40-50	60-70	
7	Total No. of Trips/day	95-110	90-100	
8	No. of Transfer Stations	1	1	
9	Location of Transfer Stations	Dabua Vegetable Market	Mujeri	
10	Collection and Transportation	By Private Operators	• Collection by Resident welfare Association (RWA) • Transportation by Vishal Protection Force	• NGO,Neelkanth Delhi • Educational Welfare Society.
11	No. of Employees	2200	906	517
12	No. of Colonies and Sectors	80-85	60-65	50-55
13	Collection Equipments	1793		
14	No. of Transport Equipments	60	38	

Source: Municipal Corporation of Faridabad

2.2 Study site

MSW of Faridabad city is collected, transported and disposed off by NGOs to Bandhwari landfill site .At present about, 631 TPD waste is generated in Faridabad city, out of this only 70-80% of the waste (440 MT) is collected and disposed from Faridabad and remaining 450 MT from Gurugram is dumped at this landfill site. The Bandhwari landfill site is about 25 km from the Faridabad.

The starting date of dumping is 2008 and the expected date of closing is 2030.The quantity of wastes dumped is about 890 MT and site has precipitation of 542 mm.

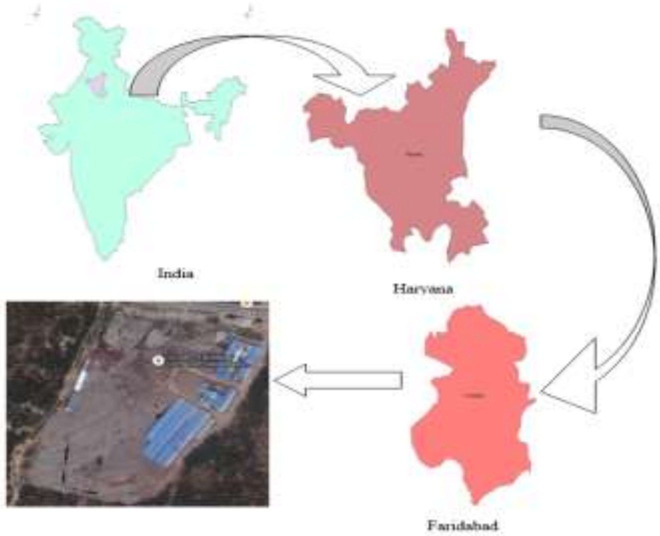

Fig. 1 Location of Bandhwari Landfill site, Faridabad [MCF]

2.3 Sample Collection and Analysis

7 MSW samples were collected from the Bandhwari landfill site and analyzed as reported in Table 2.

Table 2. Analysis of MSW samples from Bandhwari Landfill, Faridabad city (On dry basis)

Bio-Degradable Waste (%)									Non-Biodegradable Waste (%)					
Samples	**Identification**	**Latitude**	**Longitude**	**Food Waste**	**Wood /Garden Waste**	**Paper**	**Textile**	**Bio-Degradable Waste**	**Poly-thene**	**Plastic**	**Glass /Metal**	**Stone**	**Inert (soil)**	**Non-Biodegradable Waste**
S1	Near outer boundary	28°24'12.03"	77°10'22.11"	14.36	5.10	-	30.5	49.96	12.6	0.90	0.2	7.6	28.73	50.04
S2	Near outer boundary	28°24'12.22"	77°10'18.05"	21.43	1.80	0.90	3.4	27.53	4.1	1.20	1.81	22.5	42.86	72.47
S3	Middle of site	28°24'10.59"	77°10'17.35"	17.63	3.49	0.60	3.6	25.32	8.0	-	-	31.4	35.27	74.68
S4	Middle of site	28°24'9.44"	77°10'17.7"	22.00	3.70	-	6.2	31.90	16.1	0.80	1.0	6.2	44.0	68.10
S5	Middle of site	28°24'8.46"	77°10'17.7"	17.90	8.50	1.30	5.5	33.2	20.0	-	3.27	8.1	35.43	66.8
S6	Dried place	28°24'9.39"	77°10'18.42"	19.33	1.00	1.90	6.3	28.53	6.2	1.70	5.17	7.5	50.90	71.47
S7	Near entry gate	28°24'10.61"	77°10'20.52"	23.43	1.80	2.20	0.4	27.83	7.5	0.31	-	17.5	46.86	72.17
Average								**32.03**						**67.97**

The table 2 shows that biodegradable and non-biodegradable is 32.03% and 67.97% respectively indicating that the waste is largely consisting of non-biodegradable and accordingly has poor energy contents as evidenced by low calorific value.

2.4 Proximate Analysis

Proximate analysis of MSW samples was carried out to determine its volatile matter, fixed carbon, ash content and calorific value and the results are reported in table 3.

Table 3. Proximate Analysis of MSW Samples of Bandhwari landfilling site, Faridabad (Dry Basis)

Samples	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)	Calorific Value(Kcal/Kg)
S1	24.95	74.65	0.4	1489
S2	27.63	69.78	2.58	1420
S3	27.38	71.23	1.38	1380
S4	26.37	77.13	3.70	1447
S5	29.13	72.81	2.13	1422
S6	21.48	79.17	2.90	1383
S7	26.30	80.11	4.41	1454
Average	**26.17**	**74.98**	**2.5**	**1428**

The above table shows that the waste has very poor fixed carbon and volatile matter giving poor energy. The poor energy contents of wastes are due to high ash content. Based on [24] & [25], the suitability of wastes based on proximate analysis is for combustion/ Incineration or bio-gasification. Considering energy contents of the wastes and efficiency of power conversion system [11], Waste is found to have a power potential is of 10 MW if the waste is properly managed and converted to energy.

3. Estimation of GHGs from Integrated Management of MSW of Faridabad

It is divided into the following sub headings:

3.1 GHG Emission from transportation of wastes [26]

Collection and transportation of waste from the generation point to landfill site consumes significant amount of fossil fuel which leads to GHGs emissions to the atmosphere. Transport vehicles used to transfer the MSW to the landfill site is given in table 4.

Table 4. Transport Vehicles to transfer the MSW to landfill site in Faridabad [MCF]

Type of Vehicle	NIT Faridabad to Dabua Transfer Station					Old Faridabad & Ballabgarh to Mujeri Transfer Station				
	Number of vehicles	Total No of trips/day (Average)	Capacity of Vehicles (Tones)	Fuel Consumption (Km/l)		Number of vehicles	Total No of trips (Average)	Capacity of Vehicles	Fuel Consumption (Km/l)	
				Loaded Vehicle	Empty Vehicle				Loaded Vehicle	Empty vehicle
Compactors	4	9-10	7	8	2	5	11	7	8	2
Dumper Placers	8	15-20	1-2	10	3	6	20	1-2	10	3
Truck Tippers	5	15-20	2	10	3	4	15	2	10	3
Tractors	9-10	15-20	1-1.5	10	3	25	34-40	1-1.5	10	3
Auto	2	10	0.3	15	7	NA	-	0.3	15	7
Dumpers	1	2	10	5	2	1	-	10	5	2
Dumpers	1	1	15	5	2	2	-	15	5	2
Hook Loaders	5	12-15	8-10	8	2	5	-	-	8	2
Animal Catch Van	NA					3	1	1-2	15	7
JCB	NA					9	2	-	5	3
	Dabua Transfer station to landfilling site					**Mujeri Transfer station to landfilling site**				
Hook Loaders	5	11-12	15-20	8	2	5	9-10	15-20	8	2
Total	**40**	**96**	**63**	**79**	**26**	**60**	**94**	**55**	**99**	**36**

(-):Data not available

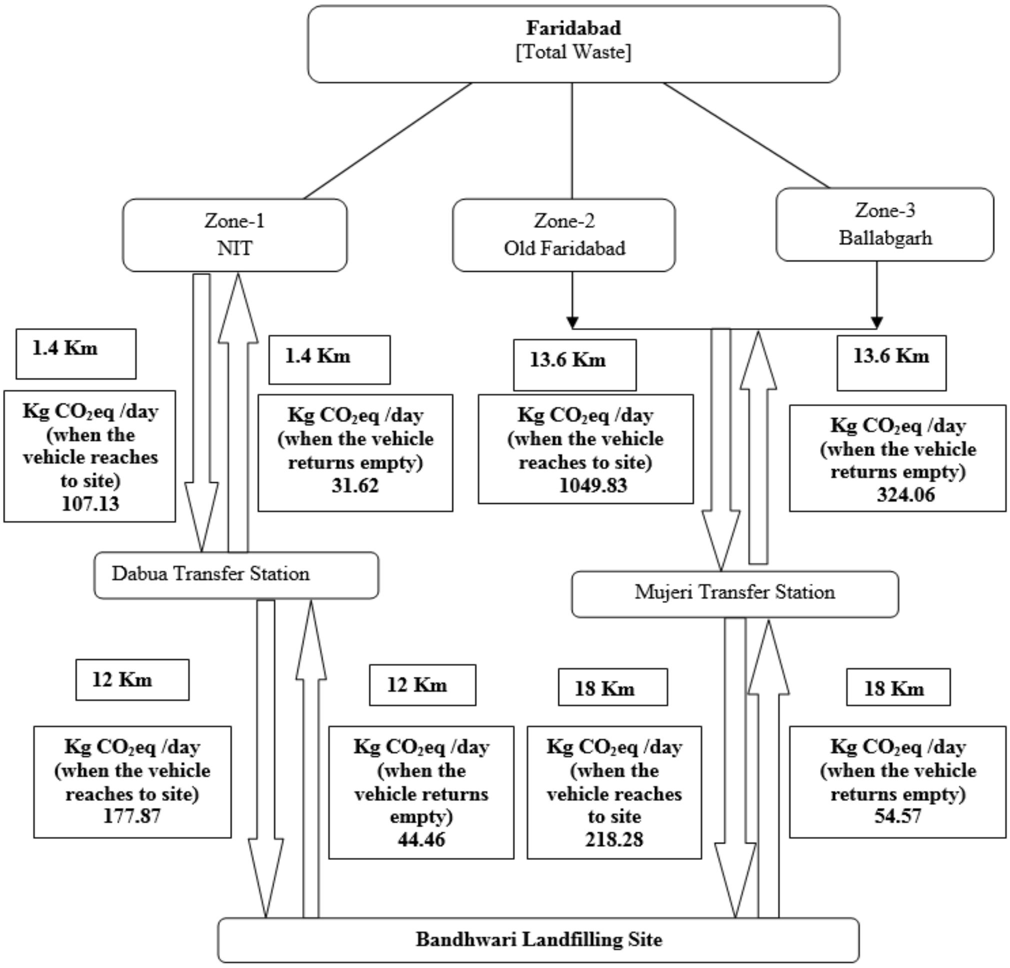

Fig. 2 Flowchart showing total emission from transportation Sector

Fig. 2 shows that all the emissions are converted to Kg CO_2eq/ day of all the 3 zones. The GHG emission during collection and transport of MSW is shown in Fig 2.The GHGs emissions from the transportation sector is calculated 2008 Kg CO_2eq/ day, from which the GHGs emission by transport to zone-1, zone-2 and zone-3 is calculated as 361.09, 930.11 and 716.64 Kg CO_2eq/day respectively. The total emissions when the vehicle is loaded with waste and reaches to the site is found as s1553.11KgCO_2eq/day while total emission when the vehicle is empty and return from the site is found as 454.71KgCO_2eq/day. This shows that higher emission occurs, when the vehicle is loaded with wastes compared to empty vehicles.

3.2 Estimation of GHG from MSW dumping site [23, 27, 28]

Three models namely IPCC Default, First order Decay (FOD) and LandGEM model were used for the estimation of GHGs from the MSW dumping site. IPCC Default method is based on zero order reaction while the FOD and LandGEM model on first order reaction. Models suitability depends on the available data like composition of waste, quantity of waste and the age of the waste. Parameters required to estimate CH_4 emission from Bandhwari Landfill site are given in table 5.

Table 5. Parameters estimate CH_4 emission from Bandhwari Landfill site

Sr.No	Model Parameter	IPCC Default Method (DM)	LandGEM Model	First order Decay (FOD)
1.	Fraction of MSW Disposed off(MSW_F)	0.64	-	0.64
2.	Methane correction Factor (MCF)	0.8	-	0.8
3.	Degradable Organic Carbon(DOC) (Gg/Year)	0.092	-	0.092
4.	Fraction of DOC Dissimilated (DOC_F)	0.7	-	0.7
5.	Oxidation Factor (OX)	0	-	0
6.	Fraction of CH_4 at Landfill site (F)	0.5	0.5	0.5
7.	Methane Generation Rate(K)($Year^{-1}$)		0.027	0.027
8.	Methane Yield(L_O) (m^3/Mg)		47.97	47.97

Using the above methods and data of table 5, the contribution of emission from zone-1, zone-2, and zone-3 waste in Gg/year is given in the Fig 3, 4 and 5.

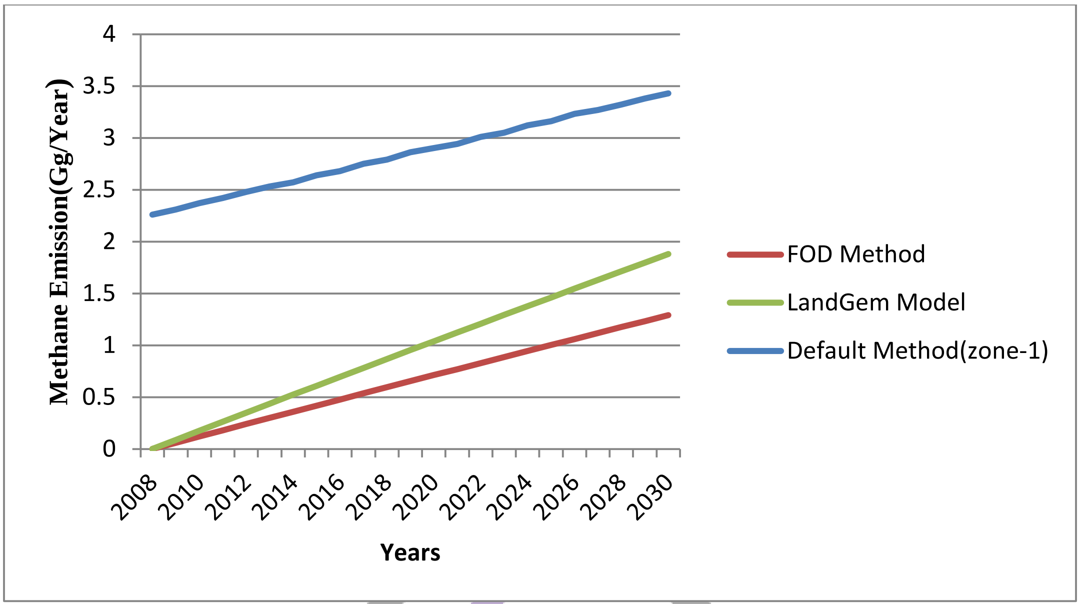

Fig. 3 CH_4 emission fromBandhwari landfill site (Zone-1) Faridabad

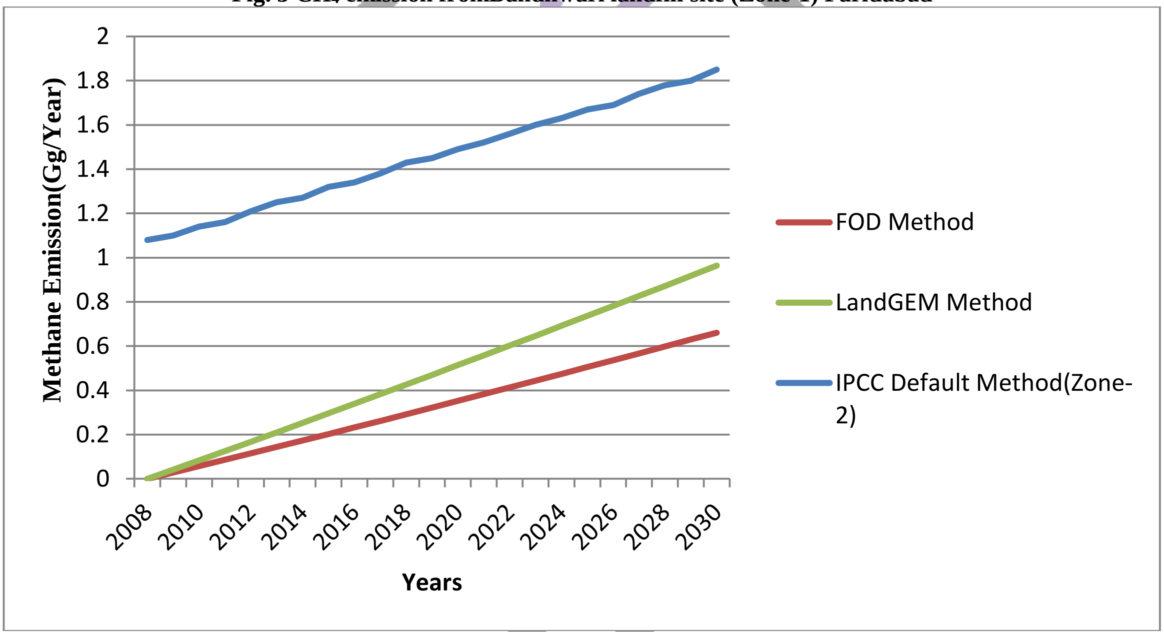

Fig. 4 CH_4 emission from Bandhwari landfill site (Zone-2) Faridabad

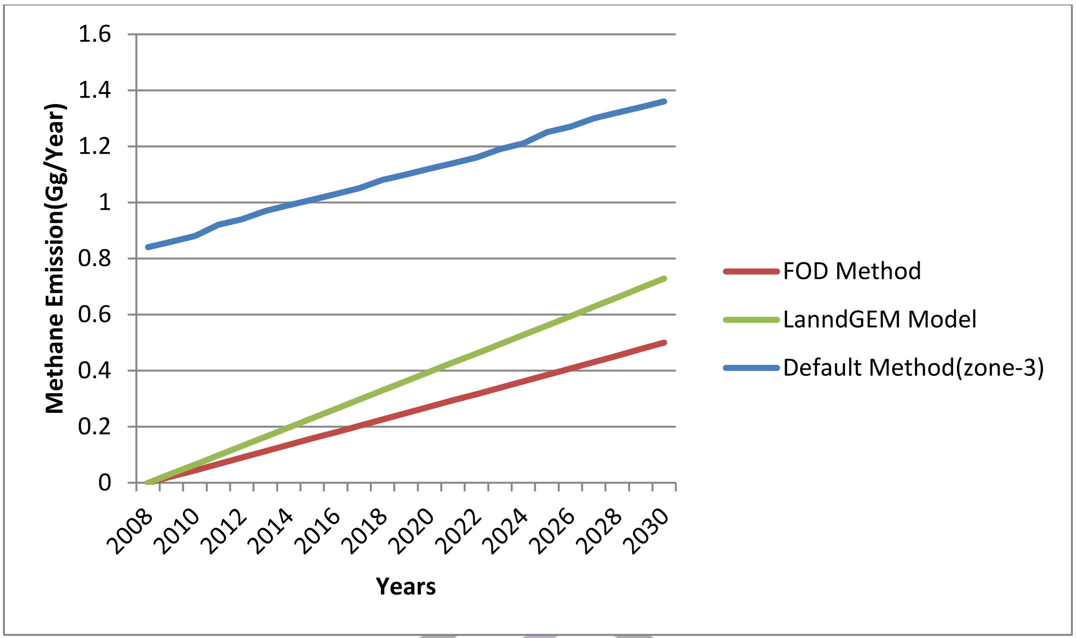

Fig.5 CH4 emission from Bandhwari landfillsite(Zone-3) Faridabad

The Contribution of zone-1 waste in CH_4 emission from dumping site is calculated by default Method; first order Decay and LandGEM model as 65.47, 14.95 and 21.80 Gg/year respectively. Fromzone-2, it is found as33.46, 7.47 and 10.90Gg/year and zone-3 waste as 25.33, 5.72 and 8.34Gg/year from 2008-2030. Annual average emission from zone-1 waste calculated by default method, FOD and LandGEM model is found as 2.84, 0.65 and 0.94 Gg respectively, from the zone-2 it is 1.45, 0.32 and 0.47 Gg and from zone-3, it is 1.10, 0.24 and 0.36 Gg.

The results show that Default method gives the higher value of emission while the FOD and LandGEM model gives almost similar results. Therefore, LandGEM is recommended over FOD due the simplicity in model parameters and avoidance of over estimation for GHG emission from MSW.

3.3 Reduction in GHG Emission by Recycling of materials [29]

In table 6, the gross value is the total GHG emissions before accounting for avoided primary material or energy production and the net value is the total GHG emissions including avoided primary production. The negative value represents a GHG emissions saving.

Table 6. Reduction in GHGs emission from Faridabad using recycling of materials

Sr. No.	Components	Quantity (tonne/Year)	Gross kgCO_2eq/ Tonne	Net kg CO_2eq/Tonne	Emission Reduction (Tonne CO2 eq/Year)
1.	Paper	2275.35	559	-120	-273.04
2.	Plastic	1617.00	339	-1024	-1655.80
3.	Glass	2490.18	395	-314	-781.91
4.	Metal	1067.22	883	-3577	-3817.44
	Total				**-6528.19**

Table 6 shows, if recycling of material such as paper, plastic, Glass and Metal from Faridabad site is done, the total reduction in GHG_S of the order of -6528.19Tonne CO2 eq/Year can be achieved. If the recycling is not done the more GHGs will be released into the atmosphere and contribute in global warming impacts.

4. Results

To determine the trend of CH_4 emission, these models were first applied to 3 landfill site of Delhi such as Ghazipur, Bhalswa and Okhla [12]. The waste composition plays an important role in the estimation the GHGs. To calculate these emissions, the data were taken from chakraborty et al. Due to the difference in waste composition, the GHG emission also varies. Degradable Organic carbon (DOC) for Ghazipur, Bhalswa and Ohkla is taken as 0.15, 0.15 and 0.14 respectively. The CH_4yield is calculated for the all 3 site as 42.90, 42.90 and 40.04 m^3/Mg.The CH_4 generation rate is taken as 0.032 $year^{-1}$.

Table 7.Comparison CH_4emission with literatures

Sr. no.	Landfill site	Methodology Adopted	Reported CH4 Emission (Gg/Year)	Estimated CH4 Emission(Gg/Year)			Ref.
				DM	FOD	LandGEM 3.02 Version	
1.	Ghazipur	Default Method(DM) First Order Decay(FOD) First Order Decay(FOD)	14.6 13.3 15.3	15.12	6.59	7.17	[12] [4]
2.	Bhalswa	Default Method(DM) First OrderDecay(FOD)	23.6 10.6	24.30	5.25	6.05	[12]
3.	Okhla	Default Method(DM) First Order Decay(FOD)	7.5 7.2	8.44	3.53	4.11	[12]
4.	**Bandhwari, Faridabad (2030)**			**6.64**	**2 .45**	**3.57**	**This Study**

From the above table, it is concluded that the reported CH_4 emission value from three sites is found different from the estimated CH4 emission. This difference is attributed to the different parameters used for the estimation. It has been noticed that FOD and LandGEM model gives nearby the same value. Similar results are obtained in study area, in which FOD and LandGEM yielded nearby the similar value. From Bandhwari landfill site, the projected emission calculated by the FOD and LandaGEM is found as 2.45 Gg/Year and 3.57 Gg/Year respectively in 2030.

4.1 Cummulative GHG emission from Integrated MSW management of Faridabad City

The composition of wastes at the generation point and dumping site are different because most of the recyclable material is picked up by rag pickers. If recycling is done at the transfer station in a proper manner, the total emission of GHG can be reduced.

Fig 6 shows Cummulative emission from Integrated MSW management of Faridabad city is found as 31375Tonne CO_2eq/Year.

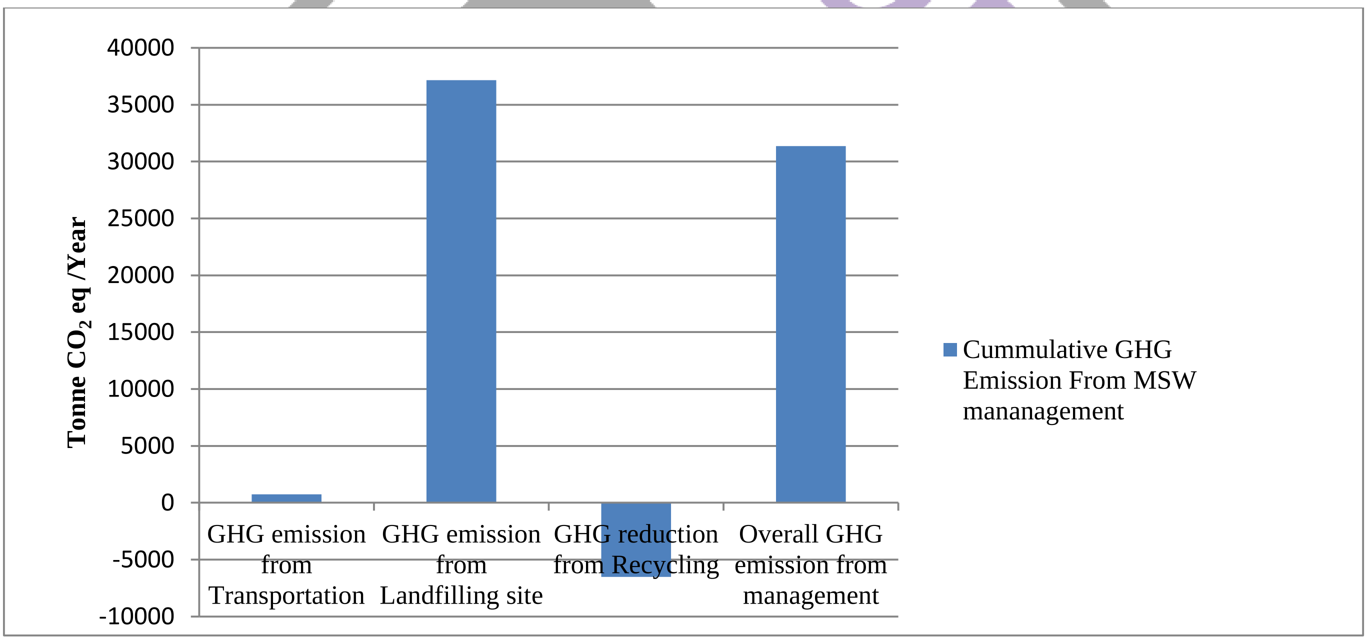

Fig. 6 Cummulative GHGs Emission from Integrated MSW management of Faridabad City

5. Conclusions

According to the waste composition of the MSW of Faridabad and the proximate analysis of the waste, this waste is found suitable for the thermo-chemical conversion process. The total power potential is found as 10 MW. The Total GHGs emission from the transportation sector is calculated 733 TonneCO_2eq/year. Annual average GHGs emission from the bandhwari landfilling site is calculated as 5.40, 1.22 and 1.77Gg using three methods. Recycling of material from the MSW, net reduction in GHGs is found as -6528.19 Tonne CO_2eq/Year .The overall GHG emission from MSW management of Faridabad city is found 31375 Tonne CO_2eq/a

6. Remedial measures

The bandhwari landfill site in Faridabad is in very critical phase. Due to the continued dumping of waste at the site, the stream of black water or leachate accumulating in the neighboring Aravalli forests as result the ground water of south Delhi, gurugram and

Faridabad is getting polluted. The foul smell attracts rats and flies around the dumping site. The waste after decomposition at the site emits GHGs such as CH_4 and CO_2. The following strategies can be adopt to reduce the GHG emission:

1. The MSW of Faridabad is more suitable for the thermo-chemical conversion process in order to recover the energy from the waste.
2. Through the recycling of material, net emission of GHGs in the atmosphere can be reduced.
3. By adopting the sanitary Landfilling the CH4 emission potential can be increased then LFG can be recovered and convert in to the energy.

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References

[1] N. Gupta, K. K. Yadav, and V. Kumar, "A review on current status of municipal solid waste management in India," *J. Environ. Sci. (China)*, vol. 37 (2015)

[2] S. By, A. Singh, R. State, P. Control, I. Area, and J. Doongri, "Municipal Solid Waste Management in Jaipur : Current Status and Way forward (Summer Internship Report Submitted in Partial Fulfillment of Post Graduate," (2011)

[3] S. Kumar, A. N. Mondal, S. A. Gaikwad, S. Devotta, and R. N. Singh, "Qualitative assessment of methane emission inventory from municipal solid waste disposal sites: A case study," *Atmos. Environ.*, vol. 38, 4921–4929 (2004)

[4] S. Mor, K. Ravindra, A. De Visscher, R. P. Dahiya, and A. Chandra, "Municipal solid waste characterization and its assessment for potential methane generation: A case study," *Sci. Total Environ.*, vol. 371, 1–10 (2006)

[5] M. Rawat and A. Ramanathan, "Assessment of Methane Flux from Municipal Solid Waste (MSW) Landfill Areas of Delhi, India," *J. Environ. Prot. (Irvine,.Calif).*, vol. 2, 399–407(2011)

[6] S. N. M. Menikpura, B. F. A. Basnayake, P. B. Boyagoda, and I. W. Kularathne, "Estimations and Mathematical Model Predictions of Energy Contents of Municipal Solid Waste (MSW) in Kandy," *Trop. Agric. Res.*, vol. 19, 389–400(2007)

[7] A. K. Jha, C. Sharma, N. Singh, R. Ramesh, R. Purvaja, and P. K. Gupta, "Greenhouse gas emissions from municipal solid waste management in Indian mega-cities: A case study of Chennai landfill sites," *Chemosphere*, vol. 71, 750–758 (2008)

[8] S. N. M. Menikpura, S. W. G. R. T. K. Ariyawansha, B. F. A. Basnayake, and Y. G. W. G. M. C. Tharinda, "Design and Development of Biofilters for Controlling Odor Emissions from Composting of Municipal Solid Waste," *Control*, 250–257 (2007)

[9] C. Paper, G. E. Strategies, B. K. Mongkut, S. H. Gheewala, and K. Mongkut, "Environmental Assessment of Municipal Solid Waste Management in Sri Lanka and India in a Life Cycle Perspective," 2–7(2010)

[10] S. Kumar, J. K. Bhattacharyya, A. N. Vaidya, T. Chakrabarti, S. Devotta, and A. B. Akolkar, "Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: An insight," *Waste Manag.*, vol. 29, 883–895 (2009)

[11] S. Jain and M. P. Sharma, "Power generation from MSW of Haridwar city: A feasibility study," *Renew. Sustain. Energy Rev.*, vol. 15, 69–90(2011)

[12] M. Chakraborty, C. Sharma, J. Pandey, N. Singh, and P. K. Gupta, "Methane emission estimation from land fi lls in Delhi : A comparative assessment of different methodologies," *Atmos. Environ.*, vol. 45, 7135–7142 (2011)

[13] F. Z. Siddiqui and M. E. Khan, "Landfill Gas Recovery and its Utilisation in India: Current Status, Potential Prospects and Policy Implications," *J. Chem. Pharm. Res.*, vol. 3, 174–183 (2011)

[14] S. N. M. Menikpura, S. H. Gheewala, S. Bonnet, and C. Chiemchaisri, "Evaluation of the effect of recycling on sustainability of municipal solid waste management in Thailand," *Waste and Biomass Valorization*, vol. 4, 237–257(2013)

[15] M. Rawat and A. Ramanathan, "Assessment of Methane Flux from Municipal Solid Waste (MSW) Landfill Areas of Delhi, India," J. Environ. Prot. (Irvine,.Calif)., vol. 2,399–407(2011)

[16] S. N. M. Menikpura, J. Sang-arun, M. Bengtsson, and G. Environmental, "Mechanical Biological Treatment as a Solution for Mitigating Greenhouse Gas Emissions from Landfills in Thailand,"17–19(2009)

[17] A. Kumar and M. P. Sharma, "Estimation of GHG emission and energy recovery potential from MSW landfill sites," *Sustain. Energy Technol. Assessments*, vol. 5, 50–61(2014)

[18] S. N. M. Menikpura, J. Sang-Arun, and M. Bengtsson, "Climate co-benefits of energy recovery from landfill gas in developing Asian cities: a case study in Bangkok," *Waste Manag. Res.*, vol. 31, 1002–1011 (2013)

[19] K. S. Woon and I. M. C. Lo, "Analyzing environmental hotspots of proposed land fill extension and advanced incineration facility in Hong Kong using life cycle assessment," *J. Clean. Prod.*, vol. 75, 64–74(2014)

[20] E. C. Rada, M. Ragazzi, P. Stefani, M. Schiavon, and V. Torretta, "Modelling the potential biogas productivity range from a MSW landfill for its sustainable exploitation," *Sustain.*, vol. 7, 482–495 (2015)

[21] A. Kumar and M. P. Sharma, "GHG emission and carbon sequestration potential from MSW of Indian metro cities," *Urban Clim.*, vol. 8, 30–41(2014)

[22] S. N. M. Menikpura, J. Sang-Arun, and M. Bengtsson, "Assessment of environmental and economic performance of Waste-to-Energy facilities in Thai cities," *Renew. Energy*, vol. 86, 576–584 (2016)

[23] A. Kaushal and M. P. Sharma, "Methane Emission from Panki Open Dump Site of Kanpur, India," *Procedia Environ. Sci.*, vol. 35, 337–347(2016)

[24] https://www.worldenergy.org/wpcontent/uploads/2013/10/WER_Waste to_Energy.pdf .

[25] T. Rand, *WTP462 Municipal Solid Waste Incineration*(2000)

[26] G. E. Strategies, "User ' s Manual A Tool for Quantification of Short Lived Climate Pollutants (SLCP) and Other Greenhouse Gas (GHG) Emissions from Waste Sector,"(2016)

[27] S. N. M. Menikpura, J. Sang-Arun, and M. Bengtsson, "Assessment of environmental and economic performance of Waste-to-Energy facilities in Thai cities," *Renew. Energy*, vol. 86, 576–584(2016)
[28] D. Surroop and M. Romeela, "Power Generation From Landfill Gas," *2nd Int. Conf. Environ. Eng. Appl.*, vol. 17,238–241 (2011)
[29] D. A. Turner, I. D. Williams, and S. Kemp, "Greenhouse gas emission factors for recycling of source-segregated waste materials," *Resour. Conserv. Recycl.*, vol. 105, 186–197 (2015).