Original Research Article

City Sanitation Analysis Based on Solid Waste Management: Case Study on Gorakhpur City, Uttar Pradesh, India

ABSTRACT

City sanitation plans are strategic planning processes for city wise sanitation sector development. Exponential increase in population and rapid economic development led to increase in generation of municipal solid waste (MSW) which impacts the sanitation of a city. Also, emission of toxic gases from MSW dumpsite are the main threat to environment and public health. In present study, data regarding solid waste management has been collected and studied the current scenario of municipal solid waste system of Gorakhpur city, Uttar Pradesh, India. MSW composition, physical and chemical analysis has been performed and Methane gases (CH_4) generated from MSW of city is quantified using LandGEM 3.02. Waste composition shows that city generates paper (6.33%), organic matter (56.1%), wood (1.36 %), textile (3.73%), plastic (1.11 %), Rubber (0.56 %), glass (1.6 %) and inert material (29.17%). With same rate of MSW generation, CH_4 emission will amount to $6.6X10^3$ Mg/yr, $1.9x10^4$ Mg/yr of CO_2 and $4.33x10^1$ Non methanic organic carbon (NMOC) by 2050. MSW analysis resulted to high moisture content of 35 -40% and organic matter of 56.1%, suitable waste to energy option that could be adopted are biogas generation, vermi composting. Rest 36% of non-biodegradable part of MSW could be converted to Reduced Derive Fuel RDF.

Keywords: Municipal Solid Waste, waste to energy, Sanitation, Greenhouse gas

1. INTRODUCTION

The physical environment and quality of life in the urban areas caused by increasing gap between demand and supply of essential services and infrastructure overshadows the positive role of urbanization. Also, it is linked with various problems such as high poverty level, environmental stress such as solid waste generation. Developing countries are majorly affected because of disposing of waste in unregulated dumps, openly burning the waste which causes serious health issues and environmental pollution [1]. World bank reports, by 2025 there will be waste production of 2.2 billion tons per year around the world. Unless an efficient waste management plan is implemented, these bulk quantities of waste could result in emission of a massive quantity of greenhouse gases, environmental degradation, and health hazard to inhabitants [2]. Inappropriate disposal and unmanaged landfills or open dumping of waste leads to the release of toxic gases like methane (CH4) in atmosphere which causes air pollution and also pollutes ground water through leachate. In view of the poor management of MSW in open dump coupled with associated climate change issues, average CH_4 emissions from MSW generated by small city such as Roorkee city , Uttrakhand, India resulted to 690 Mg/yr [3] and MSW had energy potential of 2124 Kcal/kg. which can generate energy of 28248 Kwh [4] . The composition and characteristics of MSW of Jaipur city was assessed and analysis showed that the waste has high potential to be converted to biogas since waste meets all the criteria for anaerobic digestion [5]. Also, the feasibility of waste management of Haridwar city was outlined where MSW possibility of to extract good amount of methane from the municipal solid waste and that can be used to generate power [6]. The emission of greenhouse gas from landfills of major cities such as Delhi, Kolkata and Chennai, India was quantified using conventional method such as IPCC and first order decay method resulting to 13.75 million tons of CO_2 eq. in 2011. They also focused on reduction strategies from waste sector which suggested of having need of higher tier studies to work out the actual reduction in GHGs from daily activities to prioritize mitigation strategies[7]. Apart from India, numerous country like China adopted a different approach of study done in Beijing where they quantify GHG emitted from waste before it is disposed to landfills as a city sanitation approach [8]. LFG from landfill of Sanandaj, Iran using LandGEM software obtaining total amount of LFG of 23150 tons/year. Further results observed that the amount of gas emission is more year after the closure of landfill site and aside from modelling to obtain more accurate amount of LFG, actual situation at landfill in terms of decomposition process and constant measurement of gas produced is necessary [9]. Small and green country such as Bhutan is facing issue of increase in rate of MSW generation with rapid economic development. MSW composition and its energy potential from two major landfill sites known as Memelakha (Thimphu) and Pekarshing (Phuntsholing) landfills of Bhutan were studied. The analysis showed that by the year 2050 Memelakha landfill has the potential to generate the power of 8.85 Megawatt (MW) and 1.44 Megawatt (MW) for Pekarshing. Also, for waste to energy conversion, incineration, pyrolysis, and

Comment [dp1]: typo

Comment [dp2]: write in completete for the first appear then give (IPCC)

Comment [dp3]: write in completete for the first appear then abbreviation

Comment [dp4]: write in completete for the first appear then abbreviation gasification technologies are found suitable based on the current composition MSW of aBhutan [10].

As India is world's second most populous country, and still growth rate is increasing on an alarming rate, much more quantity of MSW will be produced in future and if that waste is not managed, a significant amount of GHGs can be emitted from it. The waste dumped in the landfill sites is also not covered, which may lead to odor problems and may cause un-sanitization/ diseases to the people living around. As leachate produce from the MSW in the dumpsite, it can also penetrate to the bottom soil and may pollute the ground water. So a proper management of the MSW is very important to minimize the impacts of MSW on the environment.[11]

Comment [dp5]: Write a complete before abbreviates it

2. METHODOLOGY

Study Area

Gorakhpur is a city in the eastern part of the state of Uttar Pradesh in India, near the border with Nepal. It is the administrative headquarters of Gorakhpur District and Gorakhpur Division. The city is also home to many historic Buddhist sites, Imambara, an 18th century dargah, and the Gita Press, a publisher of Hindu religious texts. Gorakhpur is one the most populated districts of Eastern Uttar Pradesh situated. It is situated between 26°13′N and 27°29′N latitude and 83°05′E and 83°56′E longitude having long stretches of fertile alluvial plains split apart by perennial flow of gangetic1 river system. District Gorakhpur shares common boundary with district Azamgarh on south, Basti on west and district Deoria on east. It shares international border with Nepal on north. Gorakhpur city is situated 78 meter above mean sea level, which is not very high from level of river bed. It does not allow low lying areas of city to drain properly, causing water to stand for 2-3 months in a year. Rapid pace of urban expansion however is gradually rasping natural ecosystem around city by either filling low-lying areas with solid waste or building constructions on it [12].

Materials and Method

Situation analysis of the city with respect to solid waste management system including waste generation rate, segregation, collection, transportation of MSW of the city provides the overall sanitation status pf the city. For the waste generation analysis, the Population data from census 2011 to 2021 ?? has been used and the population for the year 2051 is projected using geometric method. Along with the population projection, a waste generation forecast has also been carried out.

Sample collection and waste composition analysis is carried out with reference to the *(ASTM D5231-92, 2003)*[14]. Then samples were collected from all the locations with varying depths. Each sample weight was noted on wet received basis and oven dried for 24 hours to determine moisture content. After an oven dried, each composition of MSW was calculated in terms of percentage by weight and then energy content was determined. What timing and duration of sampling ? It is suggested to be written here.

Proximate analysis

The Proximate analysis gives percentage content of moisture, ash (inorganic waste material), volatile matter (material that burns in a gaseous state) and fixed carbon (solid-state) which has been determined using standard procedure with reference to ASTM E872-82, 2019, ASTME1755 2020, ASTM D5231-92, 2003 [14][15][16] [17]. Calorific value has been obtained using Standard bomb calorimeter *(D240-19, 2019)* [18].

The equipment used and outline analysis condition should be explained here.

Sampling method should be stated fairly/ clearly !!.

Quantification of methane gas from MSW using LandGEM 3.02 Model

LandGEM 3.02 VERSION is based on first order rate equation used for quantifying the GHG emission from MSW landfill site. This method can be applied on open dump sites but in this case CH_4 emission potential should be assumed 40% that of landfill [19].

GHG emission is calculated by following equation given below:

$$QCH4 = \text{of al} \sum_{i=1}^{n} \sum_{j=0.1}^{n} KLo \left(\frac{Mi}{10}\right) e^{\wedge KTij} \qquad (1)$$

Where QCH_4: annual CH_4 generation of waste acceptance) ; i= 1 year time increment; n:(year of the calculation) – (initial year of CH4 generation capacity (m3/mg); j:0.1 year time increment; k: CH4 generation rate (year-1); Lo: potential CH_4 generation capacity (m3/mg); Mi : mass of waste accepted in the ith year(Mg);tij : age of the jth section of waste mass Mi accepted in the ith year. The required inputs for this method are design capacity of landfill annual acceptance rate (m3/year) the landfill gas generation rate constant k and landfill gas generation potential. Values of K and Lo are site specific and are given by USEPA 2005. [20].

3. RESULTS AND DISCUSSION

Situation analysis of Gorakhpur City

Solid waste management

MSW management in city is unorganized due to deficiency in infrastructure, proper disposal plan and site. Thus, MSW generated are randomly thrown along site of roads and rivers compromising the sanitation and water quality. As per the research [21], daily per capita generation of waste is found out to be 0.270 kg which extremely high compared to municipal standards which 0.375 gram.

Waste generation

The total amount of waste generation in Gorakhpur is regarding three hundred million tons per trip of that solely 250 MTs per day is being self-addressed. Household and commercial waste comprises the utmost proportion of solid waste generated. The calculable solid waste generation per day in town is shown in table 1. It was found that solely 44.73% of total solid waste is of degradable nature. The reusable waste (synthetic resin, plastic, paper cartoon) that account 13.97% of total waste are usually separate manually by rag pickers. Whereas construction waste, street sweeping and rain silt are account for thirteen.8%, 22.49% and fifth respectively [21]

Table 1 Source of waste Generation in the city

Sl.No	Category	Generation	Percentage %
1	Residential	168.13	57.86
2	Construction and demolition	41.40	14.24
3	Commercial	40.00	13.76
4	Industrial	40.00	13.76
5	Industrial	0.53	0.18
6	Clinical waste	0.50	0.17
7	Total	290.56	100

Segregation, collection and transportation of MSW

The waste segregation and recycling doesn't prevail in the waste management although the standard practice recommends MSW has to be segregated into biodegradable and non-bio degradable which further should be disposed of in separate collectors resulting in efficient waste processing and disposal mechanism. Collection of waste is very seldom done, only 10 out of 206 colonies of the city are collected which is not always regular [22]. Sometimes there are Safai karamcharis employed by NNG who is performs street sweeping, collect drain silt and waste, collects the waste alongside of roads and dispose to nearest dumping containers [23]. Wastes are transported mostly in trolleys and tractors, transported in open vehicles which have rather more effect on causing pollution of environment at the surrounding.

Issues and situation on SWM in Gorakhpur city

On basis on solid waste management situation and based on Gorakhpur Environmental action Group, some of the prevailing issues in respect to SWM that need better solution to resolve are .

- No sanitary site available for disposal/dumping all the waste generated by the city.
- Zero segregation and recycling of the waste.
- Sanitary workers don't have proper gear such as gloves, boots, mask etc to protect themselves while handling with waste on daily basis.
- Most of the waste are dumped in low lying area which is resulting in contamination of ground water due to leachate production.
- Open dumping of garbage facilitates the breeding of diseases which poses greater risk on health of people in city.
- Uncivil habits and practices: despite having 40 collection points in various location of city people living in area just dispose the waste around, side of houses, near drains, ponds not bothering to find for garbage bin nearby.

SANITATION ANALYSIS

Considering the trend of growth of the town during previous decades, population for Gorakhpur city is projected by geometric growth rate. Population data of 2011 census has been for projections for the years 2011-2051. The waste generation corresponding to the projected populations have also been computed at the city level, the per capita solid waste generation is assumed as 0.5 kg/per capita/per day shown in figure 1.

Comment [dp6]: Data primary shoud be shown

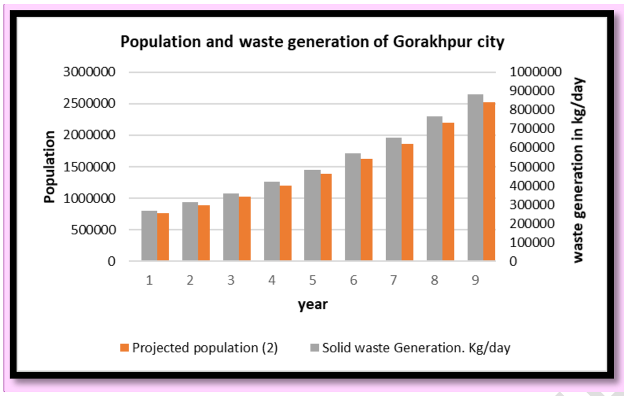

Figure 1: projected population and MSW generation of Gorakhpur City

Analysis of municipal solid waste of Gorakhpur city

MSW samples were randomly collected in garbage bag about a kilogram from various location such as dump yard, drains, and transportation vehicles. For the study purpose samples are bought to laboratory to carry out physical and chemical analysis of municipal solid waste generated in city. The present solid waste generation for the city is 3,462.57 tonnes/day (Population: 692,514). The projected population of the city in 2021 is 1.3 million, for which the estimated solid waste generation (keeping the same rate of generation) would be 6,500 tonnes/day. Low lying areas in the outskirts of the city are also being used as dumping sites. The uncollected waste becomes a cause for stagnation of water at various locations of the city. At present, the Municipal Corporation has started door-to-door collection of waste in eight wards in the city as a pilot project, which might be scaled up in future [23].

Physical Characterization of Municipal solid waste

As per the procedure applied in ASTM for collecting waste from waste points, samples were collected randomly from gullies, load trucks, dump sites as shown in Figure 1. Collected in garbage bags of 1 kg each. MSW were all mixed without any proper segregation implemented and next it's brought to lab for further analysis. Waste samples were then separated according to its classification such as paper, plastics, organic matter, metal, glass. Every sample weight was measured using weight balance. Samples were sun dried and composition in percentage is determined as shown in figure 3.

Comment [dp7]: For x axis,Year 1, 2, 3..., meaning what ??

Comment [dp8]: This quantity...representatif ??

Figure 1: Waste collected from various location

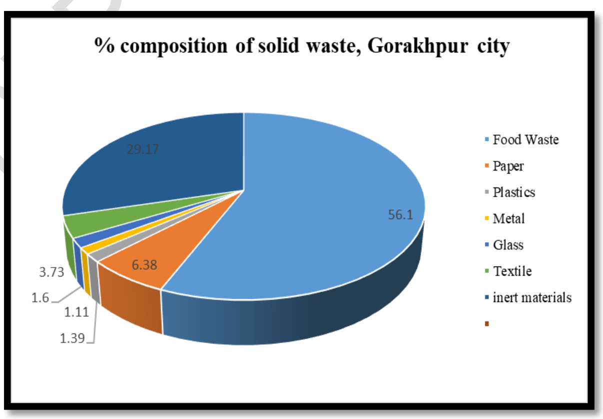

Figure 2: Physical characteristics of Solid waste of Gorakhpur City

Proximate analysis of waste samples

Proximate analysis consists of moisture content, volatile matter and fixed carbon determined by selected sample which are put to different range of temperature.

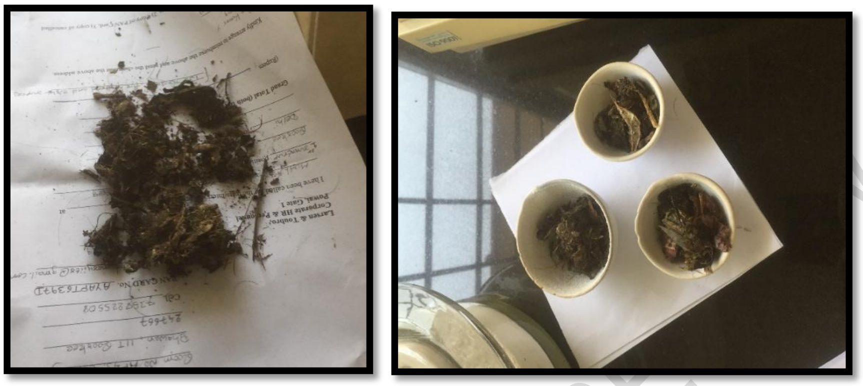

Figure 3: Proximate analysis of waste samples

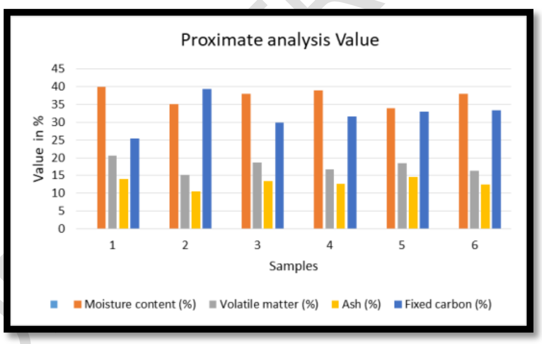

Figure 4. Proximate analysis values

Calorific Value

The calorific value means the energy content in waste based on its carbon, hydrogen content and moisture. The calorific value of the sample was determined using standard bomb calorimeter according to ASTM D240. The experimental calorific value obtained resulted to 3312.59 kcal/Kg is observably high as per the standard. It could be due to high content of organic matter in waste composition. Proper segregation is required where organic matter can be composted and used as different source of energy such as biogas and converting to manure.

Figure 6: Bomb calorimeter

Quantification of CH4 using LandGEM 3.02

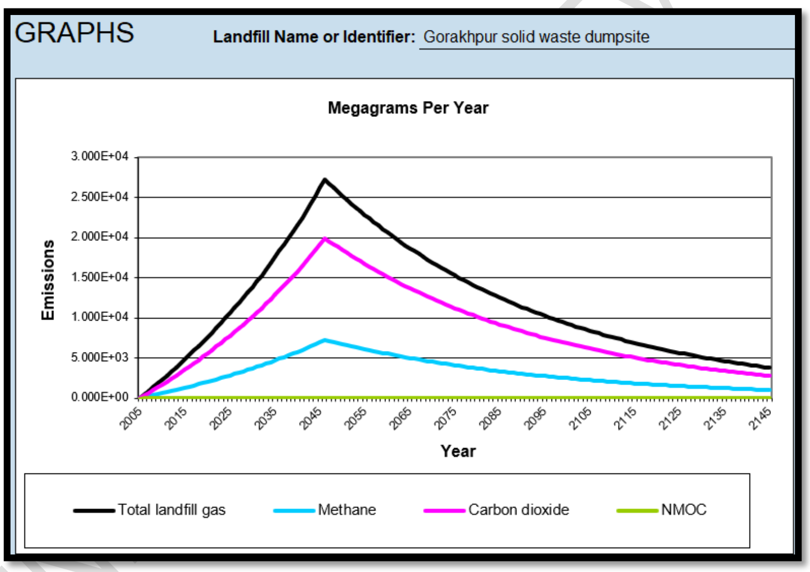

Figure 7: land fill gas generation from MSW of Gorakhpur city.

Figure 7 represents the GHG emission potential estimated by LandGEM 3.02. The feature estimates GHG emission for more than 100 years based on closing year of dumpsite and gives total GHG (CH_4 and CO_2). Since LandGEM models are usually applied only for landfills thus for open dump only 40% of the emission of landfill are considered to exist. With this CH_4 potential from 2011 to 2040 results to $6.6X10^3$ Mg/yr pf CH_4 , $1.9x10^4$ Mg/yr of CO_2 and $4.33x10^1$ Non methanic organic carbon (NMOC) by 2050.

4. CONCLUSION

Since all the waste are dumped openly without proper management such as leachate collection system, LFG monitoring and recovery system, covering of waste, buffering of dump sites are causing various pollution and sanitary problems. Waste composition of the city is paper (6.33%), organic matter (56.1%), wood (1.36 %), textile (3.73%), plastic (1.11 %), Rubber (0.56 %), glass (1.6 %) and inert material (29.17%).

Waste composition of Gorakhpur city consist of mixture of all kinds of waste which on continuous accumulation could generate $6.6X10^3$ Mg/yr of CH_4, $1.9x10^4$ Mg/yr of CO_2 and $4.33x10^1$ Non methanic organic carbon (NMOC) by 2050 and impact the Sanitation of city compromising the public health. However, gases emitted from Landfills can be turned into assets if stable waste disposal sites are viewed as opportunities for source of energy. Capturing of landfill is one of the trend in most of the countries from which it could improve landfill safety, reduce odor, generate electricity, reduce GHG emission and also earn carbon credits [24]. Analysis shows that MSW city have potential to recovery such waste that can be segregated at source and processed for recycling which is a suitable management of waste to decrease the volume of waste in landfill. Result of proximate analysis shows that due high moisture content 35 -40% and organic matter of 56.1%, it cannot be incinerated but with proper segregation, and suitable waste to energy option that could be adopted are biogas generation, vermi composting. Rest 36% of non-biodegradable part of MSW could be converted to Reduced Derive Fuel RDF.

What recommendation related to sanitation policy ??

REFERENCES

[1] S. Gupta, K. Mohan, R. Prasad, S. Gupta, and A. Kansal, “Solid waste management in India: Options and opportunities,” *Resour. Conserv. Recycl.*, vol. 24, no. 2, pp. 137–154, 1998.

[2] S. Goulette, *What a waste*, vol. 139, no. 3. 2000.

[3] Y. Choden and M. P. Sharma, “Greenhouse gas estimation from municipal solid waste dump site in Roorkee (Uttrakhand), India,” *Int. J. Res. Environ. Stud.*, vol. 6, no. 2019, pp. 39–46, 2020.

[4] M. P. Sharma and Yeshi Choden, “‘Energy potential of MSW of Roorkee city,’” *Indian J. Environ. Prot.*, vol. 40, no. 4, pp. 408–412, 2020.

[5] J.Abhishek and M. . Singhal, “International journal of Emerging Trends in Science

and Technology," pp. 374–379, 2014.

[6] S. Jain and M. P. Sharma, "Feasibility Study of Power Generation From Municipal Solid Waste of Haridwar City," *Int. J. Chem. Sci*, vol. 6, no. 4, pp. 1920–1941, 2008.

[7] S. Manuja, A. Kumar, and S. Pandey, "Greenhouse Gas Emissions and Reduction Stratagems from Waste Sector in India," no. January, pp. 17–26, 2018.

[8] C. Zhou, D. Jiang, and Z. Zhao, "Quantification of Greenhouse Gas Emissions from the Predisposal Stage of Municipal Solid Waste Management," *Environ. Sci. Technol.*, vol. 51, no. 1, pp. 320–327, 2017.

[9] R. Rezaee, S. Nasseri, A. H. Mahvi, and A. Jafari, "Estimation of gas emission released from a municipal solid waste landfill site through a modeling approach : A case study , Sanandaj , Iran," vol. 2, no. 1, pp. 13–21, 2014.

[10] Y. Choden, T. Tenzin, K. K., K. Norbu, S. Wangmo, and P. Zangmo, "Estimation of energy content in municipal solid waste of Bhutan and its potential as alternate powers source," *Environ. Conserv. J.*, vol. 22, no. 1&2, pp. 27–33, 2021.

[11] IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[12] R. K. Regmi, "Urbanization and Related Environmental Issues of Metro Manila," *J. Adv. Coll. Eng. Manag.*, vol. 3, p. 79, 2018.

[13] G. MoMSME, "Brief Industrial Profile of Murshidabad District," 2015.

[14] ASTM D5231-92(2003), "ASTM D5231-92(2003), Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste, ASTM International, West Conshohocken, PA, 1992," 2003.

[15] A. E1755, "ASTM E1755-01(2020), Standard Test Method for Ash in Biomass, ASTM International, West Conshohocken, PA, 2020," 2020.

[16] A. E872-82, "Standard Test Method for Volatile Matter in the Analysis of Particulate Wood Fuels, ASTM International, West Conshohocken, PA, 2019."

[17] A. R. Sahito, R. Mahar, Z. Siddiqui, and K. Muhammad Brohi, "Estimating Calorific Values of Lignocellulosic Biomassfrom Volatile and Fixed Solids," *Int. J. Biomass Renewables*, no. Cv, pp. 1–6, 2013.

[18] A. D240-19, "ASTM D240-19, Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter, ASTM International, West Conshohocken, PA," 2019.

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

[20] U.S. Environmental Protection Agency, "LandGEM 3.02 - Landfill Gas Emissions Model," 2005.

[21] R. W. Treatment, "INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES &

RESEARCH TECHNOLOGY Waste Generation Perspective of Gorakhpur City and Related Waste Treatment Techniques," vol. 3, no. 7, 2014.

[22] G. City and S. W. Management, "The waste of a city."

[23] S. Baranwal,PArul and Singal, "City Sanitation Plan of Gorakhpur," vol. 667, no. May, 2015.

[24] V. Rajaram, F. Z. Siddiqui, and E. M. Khan, *From Landfill Gas to Energy: Technologies and Challenges*. 2011.