Municipal Solid Waste Analysis: Case Study on Gorakhpur City, Uttar Pradesh, India

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ABSTRACT

City sanitation plans are strategic planning processes for city wise sanitation sector development. Exponential increase in population and rapid economic development led to an increase in generation of municipal solid waste (MSW) which impacts the sanitation of a city. Also, emission of toxic gases from MSW dumpsites are the main threat to the environment and public health. In the present study, data regarding solid waste management has been collected and studied the current scenario of the 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 the 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 the 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 in high moisture content of 35 -40% and organic matter of 56.1%. Based on the physio chemical analysis, suitable waste to energy option that could be adopted are biogas generation and vermi composting from the biodegradable component of MSW. Rest 36% of non-biodegradable part of MSW could be converted to Reduced Derived 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 an 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 (CH_4) in the 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 has the possibility of extracting a 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 methods such as IPCC and first order decay method resulting in 13.75 million tons of CO_2 eq. in 2011. They also focused on reduction strategies from the waste sector which suggested a need for higher tier studies to work out the actual reduction in GHGs from daily activities to prioritize mitigation strategies[7]. Apart from India, numerous countries like China adopted a different approach of study done in Beijing where they quantify GHG emitted from waste before it is disposed of to landfills as a city sanitation approach [8]. LFG from landfill of Sanandaj, Iran using LandGEM software obtaining a 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 a 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 countries such as Bhutan are facing an issue of increase in the 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 gasification technologies are found suitable based on the current composition MSW of Bhutan [10].

As India is world's second most populous country, and still growth rate is increasing at 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 is produced from the MSW in the dumpsite, it can also penetrate to the bottom soil and may pollute the groundwater. So a proper management of the MSW is very important to minimize the impacts of MSW on the environment [11].

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. 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 Gangetic River system. Gorakhpur shares a common boundary with district Azamgarh on south, Basti on west and district Deoria on east. It shares an international border with Nepal on the north. Gorakhpur city is situated 78 meter above mean sea level, which is not very high from the level of the river bed. It does not allow low lying areas of the city to drain properly, causing water to stand for 2-3 months in a year. Rapid pace of urban expansion however is gradually rasping the natural ecosystem around the city by either filling low-lying areas with solid waste or building constructions on it [12].

Materials and Method

Situation analysis of the city is performed with respect to solid waste management systems including waste generation rate, segregation, collection, transportation of MSW of the city, which provides the overall sanitation status of the city. For the waste generation analysis, the Population data from census 2011 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 0.5 to 1.5 m. Each sample weight was noted on a 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.

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].

Quantification of methane gas from MSW using LandGEM 3.02 Model

LandGEM 3.02 VERSION is based on the 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:

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

Where QCH_4: annual CH_4 generation of waste acceptance) ; i= 1 year time increment; n:(year of the calculation) – (initial year of CH_4 generation capacity (m3/mg); j:0.1 year time increment; k: CH_4 generation rate (year^{-1}); Lo: potential CH_4 generation capacity (m^3/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 (m^3/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 the city is unorganized due to deficiency in infrastructure, proper disposal plan and site. Thus, MSW generated are randomly thrown along the side 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 is extremely high compared to municipal standards which is 0.375 gram.

Waste generation

The total amount of waste generated in Gorakhpur is approximately three hundred million tons per trip of which 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 separated manually by rag pickers. Whereas construction waste, street sweeping and rain silt account for 14%, 8% and 22.49% 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 nonbio 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 perform street sweeping, collect drain silt and waste, collect the waste alongside roads and dispose of it 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 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 with 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 waste on a daily basis.
- Most of the waste is dumped in low lying areas 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 to the health of people in the city.
- Uncivil habits and practices: despite having 40 collection points in various location of the city, people living in area just dispose of the waste around side of houses, near drains, ponds not bothering to find garbage bin nearby.

Analysis of municipal solid waste of Gorakhpur city

Considering the trend of growth of the town during previous decades, the population for Gorakhpur city is projected by geometric growth rate. Population data of the 2011 census has been used 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 (refer figure 1).

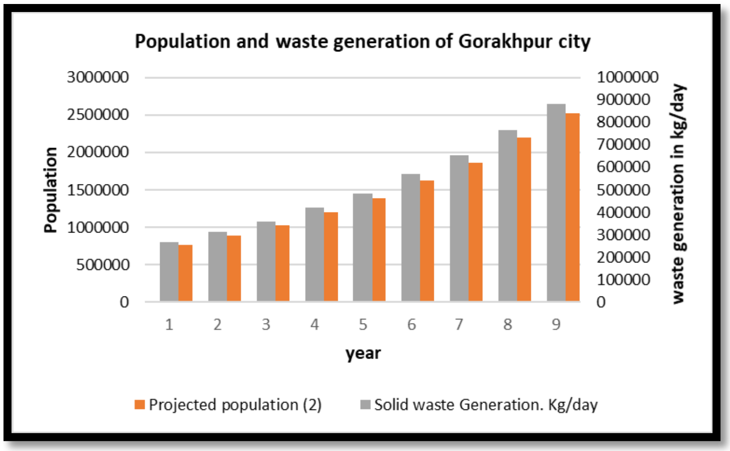

Figure 1: projected population and MSW generation of Gorakhpur City

MSW samples were randomly collected in garbage bags about a kilogram from various locations such as dump yard, drains, and transportation vehicles (refer figure 2). Samples are brought to the laboratory to carry out physical and chemical analysis of municipal solid waste generated in the city. The present solid waste generation for the city is 3,462.57 tons/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 tons/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

MSW were all mixed without any proper segregation implemented thus was segregated at lab to study it's physical composition such as paper, plastics, organic matter, metal, glass etc. Samples were sun dried and composition in percentage is determined as shown in figure 3.

Figure 1: Waste collected from various location

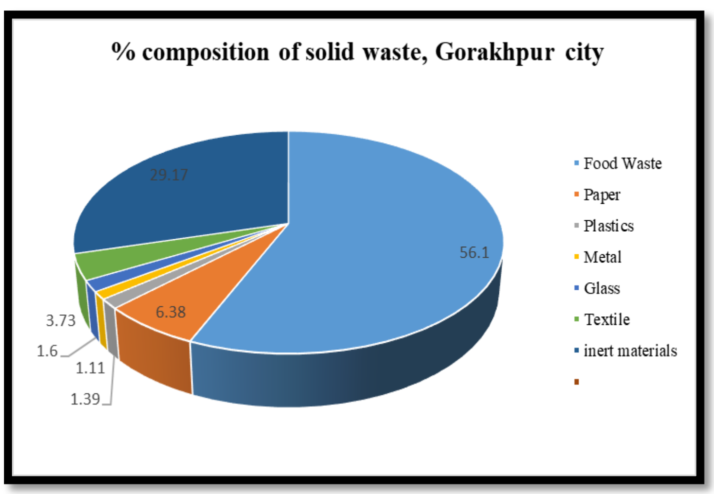

Figure 2: Physical characteristics of Solid waste of Gorakhpur City

Proximate analysis of waste samples

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

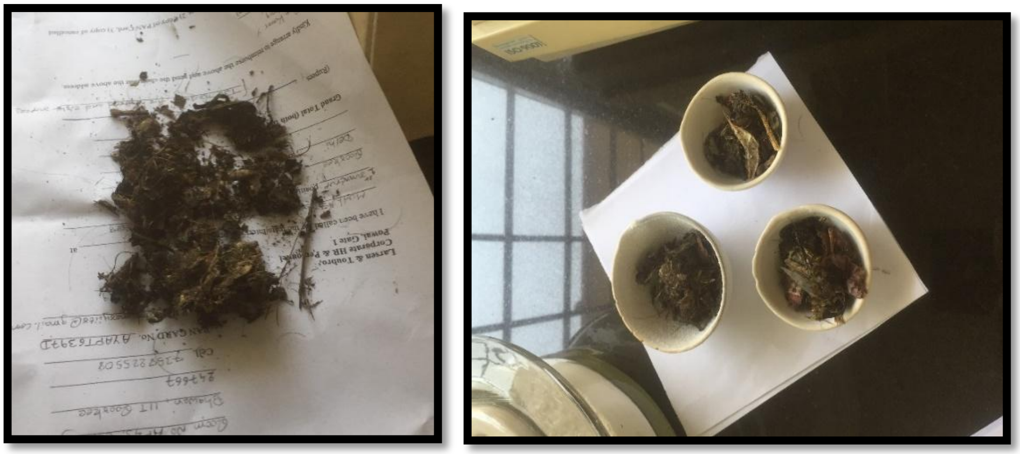

Figure 3: Proximate analysis of waste samples

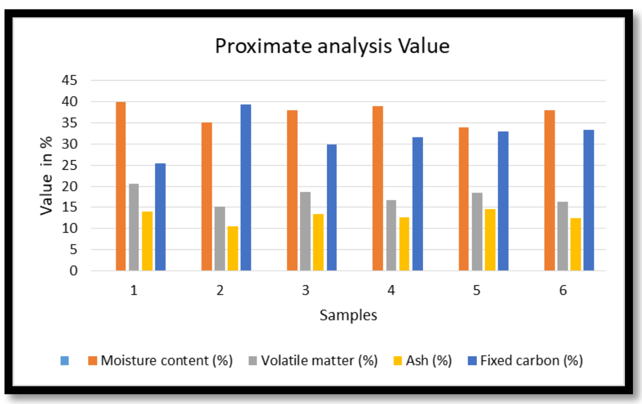

Figure 4. Proximate analysis values

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 to 3312.59 kcal/Kg is observably high as per the standard. It could be due to the high content of organic matter in waste composition. Proper segregation is required where organic matter can be composted and used as a different source of energy such as biogas and converting to manure.

Figure 6: Bomb calorimeter

Quantification of CH4 using LandGEM 3.02

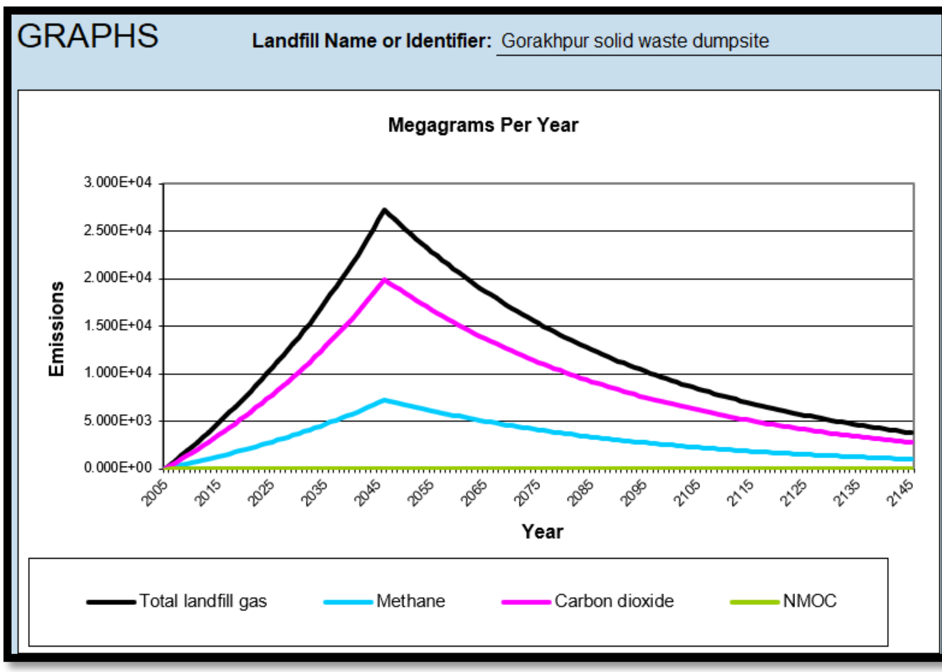

Figure 7: landfill gas generation from MSW of Gorakhpur city.

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 options that could be adopted are biogas generation, vermi composting. The remaining 36% of non-biodegradable part of MSW could be converted to Reduced Derive Fuel RDF.

COMPETING INTERESTS

Author declares non competing interest.

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