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Power Generation using Municiple Solid Waste Produced in Greater Noida – An Emerging city of U.P., India

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***Abstract*— Now a days municipal solid waste management is a topic of major concern around the globe as it can lead to many health effects on human beings as well as can cause many ill effects to the environment. The major concern which are creating problem in municipal solid waste management is the increasing per-capita waste production and its disposal. In India, according to Central Pollution Control Board (CPCB) the waste generation rate in different cities and states are increasing day by day due to increasing population and urbanization, but there disposal and treatment are neglected. In this paper a study of municipal solid waste management on Greater Noida is conducted and methods to produce fruitful results using this waste, are discussed. Greater Noida produces approximately 150-175 TPD of waste hence the major concerning points of this study are waste generation, waste collection, mode of transportation and its disposal in city. In this paper the total energy which can be recovered from the waste generated in Greater Noida is also calculated.**

Keywords—MSW; Power generation; Solid waste management; Waste disposal; Thermochemical conversion; Biochemical conversion.

I. INTRODUCTION

Municipal solid waste consists of non-hazardous waste from residential, commercial and industrial areas. Municipal solid waste also consists of market waste, yard waste, agricultural wastes and street sweepings. Hazardous waste is not considered as municipal solid waste. According to MSW Management and Handling Rules 2000 Municipal solid waste is defined as the waste which is generated from commercial and residential areas excluding hazardous waste and including treated biomedical waste. Municipal solid waste generation rate in developing countries is increasing day by day due to increasing population levels, booming economy, rapid urbanization and rise in community living standards [1]. In India the MSW amount is going to increase significantly as the nation is going to attain a industrialized status by 2020 [2].A large amount MSW generated per day in metropolitan cities of India due to unavailability or unsuitable facilities for treatment and disposal. MSW generated every day is amassed at every nook and corner because of poor collection and inadequate transportation facilities [3]. The MSW generated is disposed in low lying areas without any operational control or precautions which is the major threat to the environment of India megacities. Public and the concerning authorities never took up MSWM seriously and now it is piled up and threatening the environment and the living beings [5],[6],[7].The waste minimization and its segregation at the source are the best ways to reduce the ill-effects on the environment and will benefits financially also. Various studies reveal that about 90% of MSW is disposed of unscientifically in open dumps and landfills, creating problem to public health and the city environment.

The adverse effects on environment due to un-scientific management of waste disposal are as follows:

- Ground and surface water pollution
- Air pollution due to bad odour of the waste.
- Greenhouse gases
- Harmful effects of rats, stray animals, flies, mosquitoes, germs and other insects.
- Increase in acidity of soil near the garbage heaps.
- Probability of diseases and epidemics.
- Health related problems for rag pickers.

II. HISTORICAL REVIEW

There are many factor influencing the functional element of MSWM. The waste generation is effected by family size, their education level and income [8]. Active support and investment of real estate Company, community residential committee's involvement for public participation and fee for collection service based on volume or weight of the waste affects the household attitude towards the waste segregation at source [9].

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Past researches have shown that stakeholder or people or organization may have an interest in minimizing the waste with adequate waste management [10]. National and local government bodies are termed as stakeholder, municipal authorities and City Corporation, private bodies such as NGO's and recycling companies, ministries and the private contractors are also termed as stakeholder [8], [11]. Improper bin collection system, poor route planning, information about collection schedule, insufficient infrastructure, poor roads and number of vehicle for waste collection are the major factors that affects the collection, transfer and transportation practices of waste management [12],[13],[14]. The effective ways of extending affordable waste collection services are organizing informal sector and promoting micro-enterprises [15]. The other and the important factor affecting the treatment of waste is lack of knowledge of treatment system by authorities [16].

The waste disposal choice is affected by the supply of waste facilities. The waste from the residential areas is dumped into open areas and roadside due to lack of supply of waste containers and longer distance to these containers [17]. The safe disposal of waste in well prepared and engineered landfills is less due to the insufficient financial resources and absence of legislation [18].

Municipalities and government bodies are also lacking in technical skills among personnel which is one of the factors influencing the waste management system [12].The efficiency of waste management system can be improved by the involvement of private sector [15].Researchers have recognized that the development of integrated waste management system can take place through a positive contribution of legal framework [19].

III. THEORY OF MSW

MSWM consist of several functional elements which are generation, collection, storage, transportation and disposal. According to CPHEEO, 2000 the efficiency of MSW collection is below 70% in India. According to World Health Organization (WHO) the poor collection and bad disposal system causes around five million deaths due to the diseases caused by them. Around twenty two diseases are caused by poor collection and faulty disposal system (WHO). As per Ministry of Urban Development (MoUD) the waste generated in India was around 1, 00, 00 TPD in year 2000. The per capita waste production in small, medium, large cities in India is 0.1kg, 0.3-0.4kg and 0.5kg respectively (CPCB).

TABLE I. WASTE GENERATION RATES OF DIFFERENT STATES IN INDIA (SOURCE: CPCB2000)

S. N.	State	Per capita waste generated (kg/day)	S. N.	State	Per capita waste generated (kg/day)
1	Andhra Pradesh	0.364	12	Maharashtra	0.378
2	Assam	0.223	13	Manipur	0.201
3	Bihar	0.280	14	Meghalaya	0.157
4	Gujarat	0.451	15	Mizoram	0.296
5	Haryana	0.276	16	Orissa	0.336
6	West Bengal	0.321	17	Punjab	0.312
7	Delhi	0.475	18	Pondicherry	0.295
8	Himachal Pradesh	0.427	19	Madhya Pradesh	0.316
9	Karnataka	0.376	20	Rajasthan	0.355
10	Kerala	0.393	21	Tamil Nadu	0.467
11	Uttar Pradesh	0.381	22	Tripura	0.210

After the waste generation next functional element of MSWM is waste collection which is carried out in many ways. In India the waste collection procedure from residential areas may differ from city to city and sometimes even within the city. The waste collection can be carried out by Door to Door collection or community bin collection. Mostly in India the waste is collected by either Door to Door collection or it is thrown away on low lying areas which are the major causes of diseases and environmental degradation. The waste is collected from the resident and the commercial area by the means of auto trippers, bullock kart, rickshaw, mechanical sweeper etc. The waste collected from the source is transported to the meeting point where the waste is transferred to the large capacity tripper truck or compacter which is further transported to the disposal site where the waste is treated by different techniques The techniques such as incineration, pyrolysis are used to minimize waste and there by-products are used for some beneficial work such as production of electricity. The treatment or technique used to minimize the waste at disposal site depends upon the physical and chemical characteristic of waste as well as its composition. Physical and chemical characteristic of some cities and states have been discussed in Table II and III.

TABLE II. Chemical Characteristics Of Msw In Indian Cities On Account Of Population (Source: Neeri Report Strategy Paper On Swm In India, August 1995)

Population range(in millions)	Nitrogen	Phosphorus as P2O5	Potassium as K2O	C/N ratio	Calorific value kcal/kg
0.1-0.5	0.71	0.63	0.83	30.94	1009.89
0.5-1.0	0.66	0.56	0.69	21.13	900.61
1.0-2.0	0.64	0.82	0.72	23.68	980.05
2.0-5.0	0.56	0.69	0.78	22.45	907.18
5.0 and above	0.56	0.52	0.52	30.11	800.70

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TABLE III. PHYSICAL CHARACTERISTICS OF MSW IN INDIAN CITIES (SOURCE CPCB 2000)

Characteristics (% by weight)								
Name of metrocity	Paper	Textile	Leather	Plastic	Metals	Glass	Ash, fine earth and others	Compostable matter
Ahmedabad	6.0	1.0	–	3.0	–	–	50.0	40.00
Banglore	8.0	5.0	–	6.0	3.0	6.0	27.0	45.00
Bhopal	10.0	5.0	2.0	2.0	–	1.0	35.0	45.00
Mumbai	10.0	3.6	0.2	2.0	–	0.2	44.0	40.00
Calcutta	10.0	3.0	1.0	8.0	–	3.0	35.0	40.00
Coimbatore	5.0	9.0	–	1.0	–	–	50.0	35.00
Delhi	6.6	4.0	0.6	1.5	2.5	1.2	51.5	31.78
Hyderabad	7.0	1.7	–	1.3	–	–	50.0	40.00
Indore	5.0	2.0	–	1.0	–	–	49.0	43.00
Jaipur	6.0	2.0	–	1.0	–	2.0	47.0	42.00
Kanpur	5.0	1.0	5.0	1.5	–	–	52.5	40.00
Kochi	4.9	–	–	1.1	–	–	36.0	58.00
Lucknow	4.0	2.0	–	4.0	1.0	–	49.0	40.00
Ludhiana	3.0	5.0	–	3.0	–	–	30.0	40.00
Madras	10.0	5.0	5.0	3.0	–	–	33.0	44.00
Madurai	5.0	1.0	–	3.0	–	–	46.0	45.00
Nagpur	4.5	7.0	1.9	1.25	0.35	1.2	53.4	30.40
Patna	4.0	5.0	2.0	6.0	1.0	2.0	35.0	45.00
Pune	5.0	–	–	5.0	–	10.0	15.0	55.00
Surat	4.0	5.0	–	3.0	–	3.0	45.0	40.00
Vadodara	4.0	–	–	7.0	–	–	49.0	40.00
Varanasi	3.0	4.0	–	10.0	–	–	35.0	48.00
Visakhapatnam	3.0	2.0	–	5.0	–	5.0	50	35.00

IV. MATERIALS AND METHODS

The functional element of municipal solid waste management are as follows:

- Waste generation
- Waste storage and collection
- Waste transportation
- Waste disposal

A. Waste Generation

The activity in which materials are identified valueless or thrown away or gathered for disposal is termed as waste generation. At present in Greater Noida the waste generation activity is not very controllable in. The main cause of increasing waste generation in the area is that it is not reduced at source that is mainly the households or residential areas.

According to Greater Noida Industrial Development Authority (GNIDA) the waste generation in Greater Noida city is about

150-175 TPD. In year 2014 the waste generation was about 163 TPD. At present the population of Greater Noida is approximately 1 lakh. Whole of Greater Noida is divided in 16 sectors which consist of around 25 thousand families which are producing 2-3 kg MSW every day. According to GNIDA each family consist of 4.06 members, therefore per capita MSW generated is 0.5-0.75kg (GNIDA).

B. Waste storage and collection

The first essential step solid waste management is the storage of waste at source. The waste generated should be stored at the waste generating point until it is collected for disposal. As discussed above such a habit is not developed in India, therefore waste is thrown here and there, which causes many health issues and environmental degradation. Figure 1 shows the garbage cans of capacity 20 kg are situated in Greater Noida at various places for the collection of MSW from the shops and for the peoples so that they do not litter the waste on the roads (GNIDA).

Fig.1.The garbage cans situated at various places in Greater Noida.

From households the waste is collected by in two ways, firstly, by the government collectors which collect the waste door to door. GNIDA have provided them with the small trucks or they are also known as auto trippers in which they collect the waste door to door in residential areas. The number of auto trippers working in Greater Noida at present is 14 and there capacity is around 150 kg. The number of labor with each auto trippers is 2(one is driver and other is collector).Figure 2 shows an auto tripper collecting the waste from a house and then the collected waste is taken by the auto trippers to the big hydraulic trucks which are placed away from the residential areas and further these trucks are disposed on dumping site.

Fig.2. Auto trippers used for waste transport in Greater Noida.

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Secondly, the Fig.3 shows the government collectors which collect the waste door to door in a rickshaw in which they store the waste and dump it directly on the disposal site. The number of rickshaw working according to GNIDA is 80 in whole area and there capacity is around 120kg.

Fig.3. Rickshaws used for door to door waste collection in Greater Noida.

GNIDA has also allotted 793 safiakaramchari (sweeper) to sweep the waste in the area and collect it in a big size dustbin and which can be further collected by the tractors afterwards. The number of tractor working at present in Greater Noida is 45 which collects the waste and dump it to the disposal site.

Fig.4. Safaikaramchari (sweepers) and big dustbins used for sweeping of waste in Greater Noida.

Fig.5. Tractor/Trolley used for waste transport in Greater Noida

Fig.6 shows Mechanical Sweeper which are also used for cleaning of the roads and collecting the small size waste such as dry leaves, dust etc. GNIDA consist of 4 such kind of equipment which are allotted in different areas and work 8 hours per day and there capacity is around 120-130kg.

Fig.6. Mechanical sweeper working in Greater Noida

GNIDA had given contract to the private companies which are looking over the waste collection and disposal.

- A.G. Enviro infrastructure pvt. Ltd.(small trucks, mechanical compactors)
- Antony waste handling cell pvt. Ltd.(mechanical sweeper)

C. Waste transportation

Waste transportation is a link between the collection and disposal of garbage at the landfill sites and for this purpose, suitable vehicles and equipment's is required. GNIDA is using various types of vehicles i.e., mini-trucks and mechanical trucks of different makes A G ENVIRO and ANTONY WEST Handling Cell having 8.6 cu m capacity directly to the nearest disposal/landfill site. Presently, GNIDA uses 22 vehicles, 4 mechanical sweeper and 45 loaders. In GNIDA area about 14 auto tippers are also used for primary collection of waste from houses. Big Hydraulic Vehicle are used for transportation of waste to disposal site. Although the available transport volume is inadequate for the GNIDA areas, the vehicles operate in two shifts and usually make one trips per shift depending upon the distance of the disposal site. Underutilization of the fleet of vehicles is a problem that results in delay in transporting the garbage from the collection points to the disposal site. The major reasons for this, improper maintenance, haphazard parking of vehicles, time lost waiting in the queue for fuelling and travelling from one workshop to another for fuelling and etc. As a result, the vehicles are found to operate only few hours in a day. The situation is further worsened by poor maintenance and proper route planning and shortage of staff.

D. Waste disposal

Presently in study area, there is no official land filling site in operations. In Greater Noida for the disposal of waste there are two unofficial site which are situated at Tusyanney and other is at Haldonimorh, Habibpur Chauhanpur Road which are presently are at litigation. The GNIDA is not responsible for the management of existing disposal sites. Further details cannot be known such as area of disposal of site, amount of waste disposed etc. because current disposal site are unofficial and are

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presently litigating. Presently a disposal site has been proposed at Astauli in an area of 125 acre which will consist of a 350 ton compost plant and 250 ton refused derived plant (RDF). The residue of from both the plant will be taken to the landfill site. In future waste to energy plant will also be constructed.

V. CALCULATIONS

Energy recovery of MSW

Mainly two methods are applied for conversion of MSW to energy which is:

1. Thermo chemical conversion
2. Bio chemical conversion

TABLE IV. Desirable range of important waste parameters for technical viability of energy recovery:

Waste treatment method	Basic principal	Important waste parameters	Desirable change
Thermo-chemical conversion -Incineration -Pyrolysis -Gasification	Decomposition of organic matter by action of heat	Moisture content Organic/volatile matter Fixed carbon Total inerts Calorific value(net calorific value)	<45% >40% <15% <35% >1200 k-cal/kg
Bio-chemical conversion -Anaerobic digestion/ Bio-methanation	Decomposition of organic matter by microbial action.	Moisture content Organic/volatile matter C/N Ratio	>50% >40% 25-30

A. ENERGY RECOVERY BY THERMO-CHEMICAL CONVERSION:

In thermo-chemical conversion all of the organic matter, biodegradable as well as non-biodegradable, contributes to the energy output:

Net Calorific Value: NCV k-cal/kg.

Energy recovery potential (kWh) = NCV x W x 1000/860
= 1.16 x NCV x W

Power generation potential (kW) = 1.16 x NCV x W/ 24
= 0.048 x NCV x W

Conversion Efficiency = 25%

Net power generation potential (kW) = 0.012 x NCV x W

If NCV = 1200 k-cal/kg.

Then,

Net power generation potential (kW) = 14.4 x W.

In greater Noida the total amount of waste generated per day is about 163 tones,
Then
Net power generation potential (kW) = 14.4 x 163
= 2347.200KW
= 2.347200MW.

Energy recovered = Net power generation potential (kW) × 24
= 2347.200kW × 24h
= 56332.800 kWh.

B. ENERGY RECOVERY BY BIO-CHEMICAL CONVERSION:

In bio-chemical conversion, only the biodegradable fraction of the organic matter can contribute to the energy output:

Total waste quantity: W (tones)

Total Organic / Volatile Solids: VS = 50 %, say

Organic bio-degradable fraction: approx. 66% of VS
= 0.33 x W
Typical digestion efficiency = 60 %

Typical bio-gas yield: B (m3) = 0.80 m3 / kg. of VS destroyed
= 0.80 x 0.60 x 0.33 x W x1000
= 158.4 x W
Calorific Value of bio-gas = 5000 kcal/m3 (typical)

Energy recovery potential (kWh) = B x 5000 / 860 = 921 x W

Power generation potential (kW) = 921 x W/ 24 = 38.4 x W

Typical Conversion Efficiency = 30%

Net power generation potential (kW) = 11.5 x W.

In greater Noida the total amount of waste generated per day is about 163 tones, then

Net power generation potential (kW) = 11.5 x 163
= 1874.500KW
= 1.874500MW.

Energy recovered = Net power generation potential (kW) × 24

= 1874.500kW × 24h = 44988.000 kWh.

The Thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-

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biodegradable matter and low moisture content. The main technological options under this category include Incineration and Pyrolysis/ Gasification. The bio-chemical conversion processes, on the other hand, are preferred for wastes having high percentage of organic bio-degradable (putrescible) matter and high level of moisture/ water content, which aids microbial activity. The main technological options under this category are Anaerobic Digestion, also referred to as Biomethanation.

VI. RESULTS

From the calculations above it is found that the average MSW produced by people of Greater Noida is sufficient to generate approx. 2 MW of power daily.

VII. CONCLUSION

The study concludes that the appropriate disposal of waste in Greater Noida would results in 1200 k-cal/kg (approx.) of energy which can be further used to generate Electrical Power up to 2-3 MW daily. Also the proper waste segregation may results in an increased amount of calorific value which in turns also enhance the power generation.

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