Utilization of Segregated Municipal Solid Waste for Generation of Electricity through Bio-methanation Technology

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Abstract: *Waste is an unavoidable by-product of human activities, Economic development, urbanization and improving living standards in cities, have led to an increase in the quantity and complexity of generated waste. Rapid growth of population and industrialization degrades the urban environment and places serious stress on natural resources, which undermines equitable and sustainable development. Inefficient management and disposal of solid waste is an obvious cause of degradation of the environment in most of the cities of the developing world. Municipal corporations of the developing countries are not able to handle increasing quantities of waste which results in uncollected waste of roads and in other public places. There is a need to work towards a sustainable waste management system, which required environmental institutional, financial, economic and social sustainability. Therefore, there is growing interest in development of cost effective and eco-friendly biogas technology both in public and private sectors, a successful technological option for municipal solid waste management. Installed Bio-methanation plant generates about 400-500 electrical units per day and 40 KW Biogas generator runs for 5-6 hrs/day. The generated power is supplied to 45 No's street lights of having 250 watts capacity at Kuvempu Nagar (Ward No. 11). During last 22 months 2640 tons of segregated municipal solid waste is treated and total 133550.00 units of electricity is generated. Apart from the fact that biogas produced is effective in reducing harmful greenhouse gas emissions, the compact design of the plant makes it convenient for use and utilizes less footprint area. The treatment of organic waste is done in closed digester hence there is no odour and organic matter is recycled to generate nutrient rich bio-manure.*

Keywords: *Biogas, Bio-Power, Organic waste, Methane.*

INTRODUCTION

Rapid Industrialization and population explosion in India has led to the migration of people from villages to the cities, which generate thousands of tons of MSW. The MSW amount is expected to increase significantly in the near future as the country strives to attain an industrialized nation status by the year 2020. Poor collection and inadequate transportation are responsible for the accumulation of MSW at every nook and corner. The management of MSW is through a critical phase, due to the unavailability of suitable facilities to treat and dispose of the large amount of MSW generated daily in the metropolitan cities Unscientific disposal causes an adverse impact on all components of the environment and human health. Generally, MSW is disposed of in low lying areas without taking any precautions or operational controls.

Therefore MSWM is one of the major environmental problem of Indian mega cities. It involves activities associated with generation, storage, collection, transfer and transport, processing and disposal of the solid waste. But, in most of the MSWM system comprises of only four activities *i.e.* waste generation, collection, transportation and disposal. The management MSW requires proper infrastructure, maintenance

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and up gradation of all activities. This becomes increasingly expensive and complex due to continuous and unplanned growth of urban areas. The difficulties in providing the desired level of public service in the urban areas are often attributed to the financial status of the municipal corporations in the city (Table 1, 2 and 3).

Table 1
Waste quantity projections for Bangalore city

Year	*Total quantity generated (MT per day)*
2012	4000
2017	5600
2022	7100
2027	9100
2032	11600

Table 2
Urban population growth and waste generation projections up to 2041 for 366 cities in India

Year	*Population (In million)*	*Per-Capita*	*Total waste generation (Th. Million Ton)*
2001	197.3	0.439	31.63
2011	260.1	0.498	47.3
2021	342.8	0.569	71.15
2031	451.8	0.649	107.01
2036	518.6	0.693	131.24
2041	595.4	0.741	160.96

Table 3
Top Ten Cities in waste generation in India

Name of the City	*Waste Generated Ton/Day*
Greater Kolkata	12060
Greater Mumbai	11645
Delhi	11558
Chennai	6404
Greater Hyderabad	5154
Greater Bangalore	4500
Pune	2724
Ahmadabad	2636
Kanpur	1839
Surat	1815

CHARACTERISTICS OF MSW

There are many categories of MSW such as food waste, rubbish, commercial waste, institutional waste, street weeping waste, industrial waste, construction and demolition waste and sanitation waste. MSW contains recyclable (paper, plastic, glass and metal etc), toxic substances (paints, pesticides, used batteries, medicines etc.) compostable organic matter (fruit and vegetable peels, food waste) solid waste (blood stained cotton, sanitary napkins, disposable syringes).

The quantity of MSW generated depends on a number factors such as food habits, standard of living, degree of commercial activities and seasons. Data on the quantity variation and generation are useful in planning for collection and disposal systems. With increasing urbanization and changing lifestyles. Indian cities, now generate eight times more solid waste than they did in 1947. Presently about 90 million tons of solid waste are generated annually as by-products of industrial, mining, municipal, agricultural and other process. The amount of solid waste generated per capita is estimated to increase at a rate of 1-1.33% annually. Many researchers have reported that MSW generation rates in small towns are lower than those of metro cities and per capita generation rate of MSW generated by 217 million people living in urban areas was 23.86 million ton/yr. in the year 1991 and 39 million ton/yr. in the year 2001. The quantity of MSW is as shown in Table 1.

The per capita waste generation rate in India has increased from 0.44 kg/day in 2001 to 0.5 kg/day in 2011, fuelled by changing lifestyles and increased purchasing power of urban Indians. Urban population growth and increase in per capita waste generation have resulted in a 50% increase in the waste generated by Indian cities within only a decade since 2001. There are 53 cities in India with a million plus population, which together generate 31.5 million tonnes per year of MSW at a per capita waste generation rate OF 500 grams/day. The total MSW generated in urban India is estimated to be 68.8 million tonnes per year (TPY) or 188500 tonnes per day (TPD) of MSW. Such a steep increase in waste generation within a decade has led stress on all available natural, infrastructural and budgetary resources. However, the time has come when the country has to address this problem with the well proven technology option and thus convert it into a golden opportunity.

Table 4
Municipal Waste Generated at Different States of India

Sl. No.	Name of the State	No. of cities	Municipal Population	Municipal Solid Waste (t/day)	Percapita generated (kg/day)
1.	Andhra Pradesh	32	10845907	3973	0.364
2.	Assam	4	878310	196	0.223
3.	Bihar	17	5278361	1479	0.280
4.	Gujarat	21	8443962	3805	0.451
5.	Hariyana	12	2254353	623	0.276
6.	Himachal Pradesh	1	82054	35	0.427
7.	Karnataka	21	8283498	3118	0.376
8.	Kerala	146	3107358	1220	0.393
9.	Madhya Pradesh	23	7225833	2286	0.316
10.	Maharashtra	27	22727186	8589	0.378
11.	Manipur	1	198535	40	0.201
12.	Meghalaya	1	223366	35	0.157
13.	Mizoram	1	155240	46	0.296
14.	Orissa	7	1766021	646	0.366
15.	Punjab	10	3209903	1001	0.315
16.	Rajasthan	14	4979301	1768	0.355
17.	Tamil Nadu	25	10745773	5021	0.467
18.	Tripura	1	157358	33	0.210
19.	Uttar Pradesh	41	14480479	5515	0.467
20.	West Bengal	23	13943445	4475	0.321
21.	Chandigarh	1	504094	200	0.397
22.	Delhi	1	8419084	400	0.475
23.	Pondicherry	1	203065	60	0.295
		299	128113865	48134	0.376

CURRENT PRACTICES OF MSW MANAGEMENT

Collection and Transportation of Solid Waste to Dumping Yard

In urban areas in India, it is the responsibility of the local authorities to collect and dispose the solid waste. Collection of solid waste from the individual houses is not generally practiced. In some specific areas house to house collection of garbage is made by refuse collectors employed by the local authorities. In some cities hand carts or pedal tricycles are used for collecting the garbage from the houses and for transferring it to on-road collection points. In some areas there are arrangements for collection of garbage from the bins located in the narrower streets by the employees of the municipalities using wheel barrows which are then placed in a large bin on the main road from where the trucks collect the waste matter. In market areas and public places the sweepers on the payroll of the municipalities collect the garbage from the place of origin and take it to a central bin, from where it is transported.

The garbage is collected by municipalities from the road side collection sites and carried away to the place of disposal by means of mechanized transport. In most of the towns the collection and transportation of solid waste to disposal sites is not done regularly. It is estimate that only 30 to 40% of the garbage generated daily is collected and sent to disposal site on that very day. Various types of vehicles, varying from bullock carts to compactors, are used for transportation. However, the general purpose open body trucks of 5 to 7 tonnes capacity are the ones most commonly used. In the smaller towns, inefficient tractor- trailers are used. In a few cities compactor vehicles are also being used. The recent trend is towards the use of container-carriers and dumper placers wherein the containers of the vehicle are themselves used as community bins.

Bio-methanation Technology

City wastes are generally rich source of nutrients and organic carbon. Their conversion into biogas is desired to serve the twin objectives of cleaning the environment, generating green power and augmenting the well-needed organic carbon in soil. Our soils are showing signs of fatigue and forcing decline in the productivity (Manna *et. al.*, 2006). The impaired soil health is due to declining of soil organic matter levels and associate nutrients (micro and macro). Therefore, there is growing interest in development of cost effective and eco-friendly biogas technology both in public and private sectors, a successful technological option for municipal solid waste management.

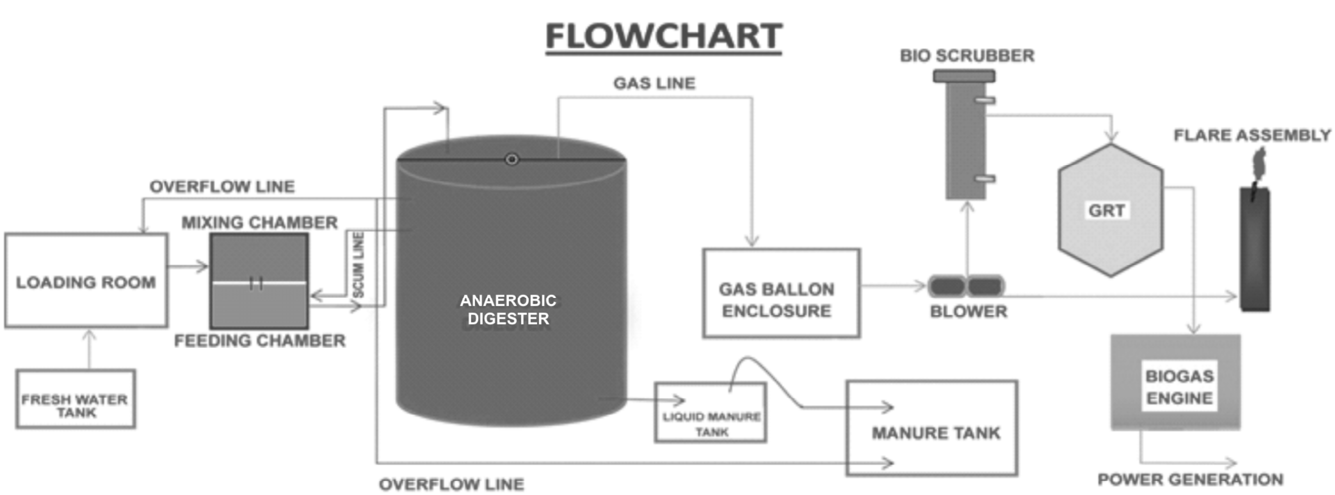
Waste Segregation

Segregation at source (garbage generating point) is the most important step in waste management and is done in two major categories: dry waste and wet garbage. The recyclable material that is separated and sent for recycling, thus preserving loss of natural resources, energy and labour which goes into its manufacturing. It also makes the job of rag pickers easy, besides providing them employment. The wet organic waste is used for generation of biogas.

A major portion (40-60 per cent) of this waste is organic in nature and can be easily treated by anaerobic digestion. The solid wastes generated in urban areas from vegetable markets, hotels, kitchen wastes etc. are best suited for this process due to the high moisture content and organic factions (upto 90 per cent). The total solids in the organic waste decompose rapidly and therefore these wastes can be treated by the bio-methanation process, more commonly called anaerobic digestion.

The bio-methanation plant at Kuvempu Nagara, (Ward No. 11), Bangalore is based on UASB (upflow anaerobic sludge blanket) technology. The sizes of the digesters for the first stage and the second stage are decided on the basis of the suspended organic contents of the slurry to be treated. The first stage fermentation is the hydrolysis stage and the second is the methanation and polishing stage. The first stage is designed to give maximum solid retention time for the hydrolysis and the second stage for acidification and biomethanation process operate in the mesophillic range.

In this process, the wet waste generated within the Kuvempu Nagar area (from household kitchens, commercial complexes, hotels/restaurants, fruit and vegetable markets wet wastes etc.) is collected and brought to the plant site by the BBMP. Through it is segregated wet waste, it still contains 2-5 per



cent non- bio-degrable material, such as plastics glass, metal etc., All such material is removed manually in the first stage, known as 'fine segregation'. Thereafter, the segregated wet waste is mixed with water in 1:1 proportion and crushed in the shredder to convert it into slurry, before being fed to the primary digester. The slurry is then treated in closed vessels called anaerobic digesters (primary and secondary digesters) where, in the absence of oxygen, microorganisms break down the organic matter into a stable residue, and generate a methane-rich biogas in the process.

Power Generation

Biogas Scrubber

The biogas generated will contain H_2S and hence the biogas needs to be scrubbed. The system provided is a proprietary Scrubber Tower using specially developed microbial culture on a packing media. Nutrients are dosed, which are essential for the growth of microorganisms. The gas and liquid is passed in counter current in the tower and "clean" gas is fed to the engine. Nutrient dosing tank along with agitator, dosing pump are used and dosage is adjusted according to the H_2S content. The biogas analysis is carried out in a small laboratory built at site.

Biogas Compressors

Compressor is used for pressurizing the biogas from the gas storage to the gas scrubbing section. For efficient combustion to take place within the 100 percent biogas fired engine, it is imperative to maintain certain minimum pressure of the biogas at the inlet of the biogas engine. Blowers are provided just before the biogas engine to consistently maintain this parameter during the engine operation.

Power Generation

The biogas engine generator set is the main heart and soul of this power generation plant. The capacity of the installed biogas engine generator set is 40 KW and having all the standard accessories and control systems. Generated electricity is used for running of street lights of Kuvempu and captive consumption.

Biogas Flare

Biogas flare is an essential item and is used to flare the biogas when not in use, excess generation or during shut down. It has a pilot flame and control valves, which will automatically flare the biogas.

Table 5
40 Kw Biogas Power Plant Highlights

Basic Information	
Process technology	: UASB Technology
Design Capacity	: 300 m^3 Biogas /day
Segregated organic waste	: 4-5 ton/day
Electricity Generation	: 400-500 Electrical Units/day 40 KW Generator runs for 5-6 hrs
Energy Yield	: Equivalent to 170 to 200 KG LPG/ DAY
Biogas Utilization	: Electricity Generation
Organic Manure	: 2 tons/day
	: (2 Tons/day organic manure × Rs. 2000/– = Rs. 4000/-)
Electricity Consumption	: 10-15 Electrical Units/day
Total Project Cost	: Rs. 79 lakhs
Payback period	: Two years

Table 6
Cost-Economics

	: 1 year	*For 3 year*
A) Revenue generation	:	
Cost of electricity @ Rs. 7.00 KWh (7 × 400 × 30 days)	: 10,08,000.00	30,24,000.00
Cost of organic manure @ Rs. 2000/ton (2*t* × 2000 × 30days)	: 14,40,000.00	43,20,000.00
Total income	: 2448000.00	73,44,000.00
B) Operation and maintenance cost		
Cost of the organic waste @ Rs. 0.50/kg (0.50 × 5000 kg × 30 days)	: 90,00,00.00	27,000,00.00
Cost of labour @ Rs. 6000/month	: 72,000.00	2,16,000.00
C) Auxiliary Consumption	: 18,000.00	54,000.00
Total	: 9,90,000.00	29,70,000.00
Payback period	1.80 Years	

CONCLUSION

The present Biogas plant generates about 400-500 electrical units per day and 40 KW Biogas generator runs for 5-6 hrs/day. The generated power is supplied to 45 No's street lights of having 250 watts capacity at Kuvempu Nagar (Ward No. 11). During last 22 months 2640 tons of segregated municipal solid waste is treated and total 133550.00 units of electricity is generated. Apart from the fact that biogas produced is effective in reducing harmful greenhouse gas emissions, the compact design of the plant makes it convenient for use and utilizes less footprint area. The treatment of organic waste is done in closed digester hence there is no odour and organic matter is recycled to generate nutrient rich bio-manure.

The benefits of Biogas Power Generation are Independence from irregular and costlier state grid power, Ensure continuity of electricity due to self-efficiency in power generation, environment friendly and also ensure getting good quality organic manure. The cost of the project is Rs. 79.00 lakhs and payback period is about two years.

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