Technological Options for Treatment of Municipal Solid Waste of Delhi

Sushmita Mohapatra ‡

* Bharati Vidyapeeth's College of Engineering

(monty_s3@yahoo.com)

‡ Corresponding Author; Sushmita Mohapatra, Bharati Vidyapeeth's College of Engineering A-4, Paschimvihar, New Delhi-110063, India, monty_s3@yahoo.com

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Abstract- The Municipal Corporation of Delhi (MCD) is among the largest municipal bodies in the world catering to an estimated population of 18 million citizens by providing civic services to them. This paper deals with the study of waste characterization survey implemented by MCD to analyze the various technological options for developing efficient management strategy.

Keywords- Incineration, composting biomethanation, waste to energy.

1. Introduction

The growth in population, urbanization and industrialization has led to the increase in the generation of solid waste all over the world. It is believed that the rate of waste generation is an index of socio-economic development and an economic prosperity of a country. This is evident from the fact that the rate of waste generation is more prominent in the developing countries where there is an increased rate of unplanned urbanization of the cities. It was estimated that about 1.3 billion MT of MSW was generated globally in 1990 [1]. At present the yearly production of solid waste in the world may be 1.6 billion MT [2]. This figure indicates that solid waste management would be a complex issue so all the technological options should be carefully investigated for an efficient waste management system.

In India the total Indian urban population amounts to approximately 285 million (Table 1). The cities which have more than 100,000 populations contribute to more than 72 per cent of the total municipal solid waste [3].

The growth rate of population in urban India is much higher than rural India. If the growth in population continues in the existing trend then the projected population in percentage of the total population living in urban areas would reach 41.4 per cent (Table 2) [4] Since waste generated by the city depends on its population and per capita income, it is estimated that the quantity of Municipal Solid Waste (MSW) would reach 17,000 – 25,000 MT per day by 2021.

Table 1. Indian Census 2001

Area of(million)	Persons Population (million)	Males Population (million)	Females Population (million)	Percentage of country Persons Males Females total population
Total	1,027	531	496	100
Rural	742	381	361	72
Urban	285	150	135	28

*Source: http://www.censusindia.net/results/rudist.html.

Table 2. Increase in Urban Population in India

	1950	1960	1970	1980	1990	2000	2005	2015(estimation)	2030(estimation)
UrbanPopulation(%)	17.3	18.0	19.8	23.1	25.5	27.7	28.7	32.2	41.4

Source: http://globalis.gvu.unu.edu/.

The Union Territory of Delhi with a population of around 18 million is one of the biggest metropolis of the world. One of the major goals of the Government is to make Delhi a centre of urban excellence; which means a well planned waste management system. Municipal Corporation of Delhi (MCD) is among the largest municipal bodies in the world catering to the needs of an estimated population of 18 million people and covering approximately an area of 1399.26 sq.km. Figure 1 shows the map of Delhi with its current existing disposal sites.

For solid waste management in Delhi, twenty landfill sites were identified and developed since 1975 of which 15 have already been closed and two were suspended. At present only three landfill sites are in operation [5] given in Table 3.

Fig. 1. Locations of existing landfills of Delhi

Table 3. Land filled sites of Delhi

S.N.	Name of SLF* site	Location	Area	Start Year	Waste Received	Zones
1	Bhalaswa	North Delhi	21.06 Ha	1993	2200 TPD*	Civil Line, Karol Bagh, Rohini, West and Najafgarh
2	Ghazipur	East Delhi	29.16 Ha	1984	2000 TPD*	Shahdara (North), Shah. (South), City, Sadar Paharganj & NDMC area
3	Okhla	South Delhi	16.20 Ha	1994	1200 TPD*	Central, South, Najafgarh and Cantonment area

* SLF: Sanitary Land Fills; * TPD: Tones Per Day.

The three sanitary landfill sites mentioned above are likely to be exhausted soon if the existing conditions are not improved. A number of technologies are being proposed for management and disposal of garbage but a commercially viable and environmentally friendly method is yet to be explored and implemented

2. Technological Options for Waste Management

The first step towards waste management is the segregation of waste into biodegradable and non biodegradable categories at source. Then the waste management system is characterized by a high degree of informal recycling conducted by rag pickers during collection of wastes and finally sending them to disposal sites or landfills [6]. This is depicted in Fig. 2.

Fig. 2. Waste recycles hierarchy in Delhi

There are proper stakeholders in this process who collect recyclables from the rag pickers and pass into recycling stream. The number of rag pickers are between 80,000 to 1,00,000 and on an average a rag picker picks up about 50 kg of waste everyday which means that there is a reduction of approximately 1,200-1,500 tones of waste everyday.

3. Estimation of Energy Content from Landfills of Delhi

The two routes by which energy can be recovered from the organic fraction of biodegradable as well as non-biodegradable waste are as follows:

(i)Thermo-chemical conversion: This process deals with thermal decomposition of organic matter to produce heat energy, fuel oil or gas. The Thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content. The main technological options under this category is Incineration.

(ii)Bio-chemical conversion: This process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol. The bio-chemical conversion processes, are preferred for wastes having high percentage of organic bio-degradable matter and high level of moisture/water content, which aids microbial activity [7].

*(iii)*The main technological options under this category is Anaerobic digestion, also referred to as Biomethanation (as shown in Table 4).

Table 4. Parameters governing various processes for energy recovery

Waste treatment method	Basic principle	Important waste parameters	Desirable range
Thermochemicalconversion - Incineration - Pyrolysis - Gasification	Decomposition of organic matter by action of heat	Moisture content Volatile matter Fixed carbon Total inerts Calorific value (Net CV)	< 45 % > 40% < 15 % < 35 % > 1200 Kcal/Kg
Biochemical Conversion - Anaerobic digestion - Biomethanation	Decomposition of organic matter by microbial action	Moisture content Volatile matter C/N ratio	> 50% > 40% 25-30

Source :[COWI, 2004]

3.1. Thermo Chemical Conversion

3.1.1. Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials at high temperatures.This process converts the waste into ash formed by the inorganic constiuent of the waste and the flue gases and heat produced can be used to generate electric power.Incineration process can also reduce the amount of waste by 85-90%. For the calculation of energy, the following parameters are important:

1) Per capita generation

2) Composition of waste in the following fractions: paper, food waste, hazardous materials, ferrous and non ferrous metals, plastics, rubber etc.

3) Properties such as bulk density, moisture content, ash content, C/N ratio which could help in designing an efficient waste management options.

Table 5. Physical composition studies (COWI, 2004)

S.No.	Composition	Products included
1	Paper	a) paper, newspaper, wrappers b) cardboard, packaging materials
2	Plastics	a) plastic bags, bottles b) plastic packaging material c) wires etc.
3	Rubber	Rubber tires
4	Vegetable / organic matter	a) vegetable matter b) food waste c) garden waste d) wood
5	Hazardous material	a) biomedical syringes b)discarded medicines, bottles containing pesticides, dry cells, electronic circuits
6	Metals	a) ferrous cables b) non ferrous foils, cables etc
7	Glass	Glass bottles
8	Ceramics	Pottery
9	Soil	Soil, sand, ash, dust, stones, construction wastes, bricks
10	Miscellaneous	Cloth and material not covered under above categories

3.1.2. Selection of Sampling Areas

The data for the present study was taken from the MCD report [8] in which first the selection of the sampling areas was done and then the survey was carried for 7 days with samples collected from 50 sites within a category. Each sample after collection was coded weighed and mixed with the other samples within the same category in a specified manner. After the surveys were conducted a comparison was made between the composition and properties of waste from different strata of society, which are detailed in Table 6.

Table 6. Comparison of waste from different sources (in percentage)

Composition	Streets	HIG	LIG	Vegetable Market	Institutional Area	Commercial Area	Landfills
Biodegradable	28.4	71.9	58.4	90.1	59.7	15.6	73.7
Recyclable	12.0	23.1	15.7	0.0-9.9	33.8	68.0	9.2
Inert	56.1	0.3	22.8	0.0-4.8	4.0	NIL	10.8
Others	3.5	4.7	3.1	NIL	2.5	16.4	6.3
Bulk density (Kg/m3)	326	267	229	202	253	57	327
Ash content(%)	56.7	10.9	21.8	3.3	6.7	8.8	15.3
Moisture (%)	19	59	54	76	50	18	47
LCV(Kcal/Kg)	1598	1623	1398	497	1693	3532	1777
HCV(Kcal/Kg)	2199	4907	3446	3827	4159	4576	3927
C/N ratio	51	31	39	16	35	158	38

Source: Feasibility study and Master Plan for Optimal Waste Treatment and disposal for entire State of Delhi based on Public Private Partnership Solutions Volume 6 Municipal Solid Waste Characterization report by MCD April 2004 [8].

Following conclusions can be drawn from Table 6:

1) The biodegradable waste was much higher in High Income Group (HIG) houses than the Lower Income Group (LIG) houses. It is because they consist of mainly food and vegetable waste.

2) The recyclable waste is highest in the commercial areas as these comprise of packing boxes, wooden boxes, papers, plastics etc. Hence the rag picker industry or the informal section of society can be encouraged as a 'small scale industry' in such areas and thus these wastes could be avoided from over burdening the landfills

3) LCV is high in the areas where the wastes contain biodegradable and recyclables. Presence of high moisture content lead to lower LCV figures. If the HCV is very high it indicates mostly recyclables and fewer amounts of organic wastes. Wherever the per centage of moisture is low, there is little difference between HCV and LCV.

4) C/N ratio decides whether the waste is suitable for composting or not. The optimum C/N ratio for composting is considered to be 30-35 %. Landfills indicate a C/N ratio of 38 which is on a little higher side than the optimum value. Hence, if the sewage sludge, slaughter house waste etc., which are sources of nitrogen are blended with waste entering landfills, then the waste would become suitable for composting and the pressure on landfills could be reduced with proper segregations and treatment.

3.1.3. Incineration Plant of Timarpur

In Delhi, an attempt was made to recover energy from waste by implementing the Timarpur Refuse Incineration-cum-Power Generation Station ("Timarpur Plant") in 1987. This plant was designed to incinerate 300 TPD of Municipal Solid Waste ("MSW") and generate 3.75 MW of electric power. The plant when put on trial could neither incinerate the desired amount of MSW nor generate 3.75 MW of electric power.

The plant failed after 21 days of trial operation because of the poor quality of MSW. The plant required waste with a net calorific value of at least 1462.5 kcal/kg but the supplied waste was in the range of 600-700 kcal/kg. Plant was operated at partial load with oil support along with available MSW, however, low calorific value of MSW could not make incineration process complete. Apart from the failure of the plant there was a public resistance also because of release of toxic gases like dioxins in the atmosphere. Also there are approximately 1,00,000 waste pickers in Delhi who recover nearly 1,600 tons or approximately 15-20 per cent of usable materials such as metal, paper, cardboard, and plastic from the city's waste. The waste pickers prevent the emission of 9,62,133 tons of greenhouse gasses annually The Incineration plant also burns mixed waste because organic food waste is high in moisture and low in calorific value so paper, plastic cardboard etc. are also burned along with it. Hence, all these factors put together led to the shut down of the first" Waste to Energy "plant of Delhi.

3.1.4. Timarpur-Okhla Waste to Energy Plant

In December 2006, the Govt. proposed another waste to energy plant in Okhla where it was decided that a plant would be set up that will process1300 tons-of MSW per-day (TPD) and would generate 450 tons of RDF per day, along with a 100 TPD bio- methanation plant that would generate 16 MW of power .There would be a three stage operational facility i.e. collection, screening and recovery of the material from MSW followed by charging to Waste to Energy (WtE) boiler. The entire operation of waste collection, segregation and feeding wouldl be done in an enclosed chamber with negative pressure so that bad odor is minimized. The temperature of the boiler would be maintained at 850oC with a minimum resistance time of 2 seconds to ensure complete destruction of organic matter. The system would operate on MSW having low calorific values of 1,000-1,400 Kcal per Kg. The flue gas clean-up operation comprises of spray adsorption towers followed by back filters to ensure reduction of PCDD (Polychlorinated dibenzodioxins) and other parameters to permissible limits [9].

3.2. Biochemical Conversion

3.2.1. Composting

A Compost Plant was installed in Okhla in 1981 for a controlled aerobic decomposition of organic waste in a windrow composting process to avoid methane emissions from anaerobic decomposition of municipal solid waste (MSW) from dump sites. The aerated composting process not only avoids methane emissions but also results in compost as a product that can be utilized as organic fertilizer. This compost plant, installed in 1981, was one of the most suitable plants for the Indian conditions due to its simple and rugged design without any pre-treatment (size reduction, sorting, etc.) of incoming MSW. The plant was operational until 2000 when it had to close due to problems in marketing of the compost and in securing a selling price that would cover its production costs. In May, 2007 IL and FS signed a concession agreement with MCD to revive, establish, finance, design, construct, operate and maintain the compost plant. The Project would treat biodegradable waste predominantly from vegetable market(s) of Delhi and on average it will divert approximately 73,000 tons of MSW per year .The Project has an additional advantage of earning carbon credits also, its operation will be made sustainable by covering the installation and operation cost through sale of compost and revenue from CDM. The term of the concession is for 25 years from the date of agreement.

3.2.2. Biomethanation

Estimation of methane from the landfills of Delhi

Landfills are considered to be one of the major sources of methane generation. Globally efforts are being made to use the energy potential of emitted methane from these sites. International Panel for Climate Change (IPCC) has deeply focused attention towards methods (empirical, stochiometric, statistical) which can be used for estimation of the generated methane from the landfill sites. Carbon dioxide and methane are the main green house gases which are emitted to the atmosphere directly from the landfills. The percentage distributions of gases found in a landfill are reported in Table 7.

In the landfills first aerobic decomposition occurs until the oxygen in the air initially present in the compacted wastes is depleted resulting in the high initial percentage of carbon dioxide. Thereafter, decomposition proceeds anaerobically [10]. As shown, after 18 months the composition of the gas remains reasonably constant. If the landfill is not vented, the percentage of methane would increase because carbon dioxide would diffuse into the strata below the landfill [11].

Table 7: Percentage distribution of landfill gases during first 48 months

Time interval since start of cell completion (months)	Nitrogen (N2)	Carbon Dioxide (CO2)	Methane (CH4)
0 – 3	5.2	88	5
3 – 6	3.8	76	21
6 – 12	0.4	65	29
12 – 18	1.1	52	40
18 – 24	0.4	53	47
24 – 30	0.2	52	48
30 – 36	1.3	46	51
36 – 42	0.9	50	47
42 – 48	0.4	51	48

Source: [10]

Composition of landfill gas

Landfill gas is usually referred to as natural gas or methane; however other gases like air, ammonia, carbon dioxide, carbon monoxide, hydrogen, hydrogen sulfide, nitrogen and oxygen. Therefore, the commonly used term landfill methane is deceiving as it implies that landfill gas is simply methane [12]. The composition of landfill gas is shown in Table 8.

Table 8. Composition of Landfill Gas [12]

Constituent Gas	Concentration in LFG	
	Range Average	Average
Methane	35 to 60%	50%
Carbon Dioxide	35 to 55%	45%
Nitrogen	0 to 20%	5%
Oxygen	0 to 2.5%	<1%
Hydrogen Sulphide	1 to 1700 ppmv	21 ppmv
Halides	NA	132 ppmv
Water Vapour	1 to 10%	NA
Nonmethane organic compounds (NMOCs)	237 to 14,294 ppmv	2,700 ppmv

NA – Not Available, ppmv – parts per million by volume.

Table 8 provides a typical compositional breakdown of landfill gas. Landfill gas is approximately 50 per cent methane. The remainder of landfill gas is mostly carbon dioxide with varying amounts of nitrogen, oxygen and assorted contaminants known as Nonmethane Organic Compounds (NMOC). NMOC usually make up less than 1 per cent of landfill gas. Many of these are toxic chemicals, such as benzene, toluene, chloroform, vinyl chloride, carbon tetrachloride and 1, 1, 1 trichloroethane.

Bacterial Decomposition in landfills

Bacteria decompose landfill waste in four phases. The composition of the gas produced changes with each of the four phases of decomposition. Landfills often accept waste over 20 to 30 year periods, so waste in a landfill may be undergoing several phases of decomposition at the same time.

3.2.3. Biomethanation Plant in Timarpur

The project has a bio-methanation facility for a combined treatment of 50 tons per day of segregated vegetable market waste and 6 million gallons per day (MGD) of sewage, which could produce biogas, equivalent of 2500 kg LPG, to be used as fuel for generating electricity. A two phase modified Up-flow Anaerobic Sludge Blanket (UASB) is adopted for this project activity. This biogas will be used as supporting fuel for the boiler and dryer in RDF plant. The disadvantage of this process is that some of the gases tend to escape through cracks and crevices by diffusion (concentration gradient) or convection (pressure gradient) mechanism posing threat to nearby structures and vegetation.

4. Conclusion

From the data obtained from the published papers, it could be concluded that like many other developing countries, SWM in Delhi till now remains the responsibility of municipality. The various technological options studied, show that every method has its own advantages and disadvantages. To achieve an efficient management system, public involvement becomes very important where emphasis should be laid to minimize the amount of waste produced and to achieve value added products from the waste.

It is seen that the landfills have a lot of potential for energy recovery which can be used for commercial applications such as power generation. Methane generated could be supplied as pipeline gas also. It could thus be proposed that the unutilized energy trapped in landfills could be properly used which otherwise is wasted adding to global warming.

Also, role and collective responsibility of urban planners, designers, government bodies and above all general public plays a vital role in effective ecological and economic solid waste management .Thus it can be concluded that solid waste generation cannot be stopped at one go and it requires innovative approaches for efficient management.

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