Energy Generation Opportunities from MSW of Ahmedabad City: A Case Study

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Abstract— **Solid waste management (SWM) is the most challenging issue pertaining in the urban cities. Enhanced population, urbanization, industrialization, improved lifestyles and changing consumption pattern are resulting in the generation of increased amount of solid waste and diversification of the type of solid waste generated. As a consequence environmental pollution and health hazard has increased to an alarming rate. A study will be conducted in Ahmedabad : a metro city of Gujarat to assess the prevailing municipal solid waste management (MSWM) system. This study is meant to identify the energy generation opportunities from MSW of Ahmadabad city. Strategies and guidelines are proposed in this study which aims to guide municipal authorities to formulate their future action plan to improve MSWM in the city considering its effect on the environment.**

IndexTerms— **Energy generation, Municipal Solid Waste, Waste Handling, Land Filling using Waste**

I. Introduction

Waste is a continually growing problem at global and regional as well as at local levels. Solid wastes arise from human and animal activities that are normally discarded as useless or unwanted. Solid wastes generally counted as organic and inorganic waste materials produced by many peoples, which have lost their value to the first user. As the result of rapid increase in production and consumption, urban society rejects and generates solid material regularly which leads to considerable increase in the volume of waste generated from several sources such as, commercial source, institutional source , industrial source and majorly domestic source of most diverse categories. Management of solid waste may be defined as that discipline associated with the control of generation, storage, collection, transfer from one place to another, processing of waste, and disposal of solid wastes in such a way that it is associated to public health of people , economy of country, engineering conservation, aesthetics of city , and other environmental considerations. In its scope, solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in the whole spectrum of solutions to problems of solid wastes thrust upon the community by its inhabitants. Solid wastes have the deep impact on air, land and water at local and at global levels. The problem is compounded by trends in consumption and production patterns and by continuing urbanization of the world. The problem is more acute in developing nations than in developed nations as the economic growth as well as urbanization is more rapid.

In India, according to the Ministry of Environment and Forests "municipal solid waste" includes commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes (MOEF, 2000). In simple words the municipal solid waste can be defined as the waste that is controlled and collected by local authority and municipality. Municipal Solid Waste. Management in India falls under the public health and sanitation and hence as per the Indian Constitution is a State responsibility. This service has always been within the public domain until very recently, that the waste management services started being privatized. The activity being local in nature has been given to local municipal authorities that provide this service with its own staff, equipment and funds.

As per the recent estimates, the country produces about 100000 MT urban solid waste daily (The Expert Committee, 2000) with typical characteristics as per the Table 1 below. The municipal waste generation in metro cities varies between 0.2- 0.6 kg/capita/day as per the detailed survey and urban MSW generation is estimated to be approximately 0.49 kg per capita per day.

II. VARIOUS STAGES IN MANAGEMENT OF SWM

The Main functional elements in the solid waste management system is waste handling, sorting, storage, and processing at the source. Waste handling and sorting involves the activities associated with management of wastes until they are placed in storage containers for collection. Handling of solid waste is mainly done in ent of loaded containers to the point of collection decided by municipalities or local authorities. Sorting of waste components is an important step in the handling and storage of solid waste at the source. For example, the best place to separate waste materials for reuse and recycling is at the source of generation. Households are becoming more aware of the importance of separating newspaper and cardboard, bottles/glass, kitchen wastes and ferrous and non-ferrous materials.

On-site storage is of primary importance because of public health concerns and aesthetic consideration. Unsightly makeshift containers and even open ground storage, both of which are undesirable, are often seen at many residential and commercial sites. The cost of providing storage for solid wastes at the source is normally borne by the household in the case of individuals, or by the management of commercial and industrial properties. Processing at the source of solid waste which mainly involves activities such as backyard waste composting.

A. COLLECTION OF SOLID WASTE

The functional element of collection, includes not only the gathering of solid wastes and recyclable materials, but also the transport of these materials, after collection, to the location where the collection vehicle is emptied. This location may have materials processing facility of materials, a transfer station of waste , or a landfill disposal site nearby.

B. SORTING, PROCESSING AND TRANSFORMATION OF SOLID WASTE

The sorting, processing and transformation of solid waste materials are the main functional elements. The recovery of sorted materials from all gather different waste, processing of solid waste as well as transformation of solid waste that occurs preliminary in locations which is away from the source of waste generation are encompassed by this main element. Sorting of commingled (mixed) wastes usually occurs at a materials recovery facility, transfer stations, combustion facilities, and disposal sites. Sorting of waste means it includes the separation of bulky items, segregation of waste components by size using screens, some times manual separation also of waste components, and separation of ferrous and non-ferrous metals. Waste processing is undertaken to recover conversion products and energy. The organic fraction of Municipal Solid Waste (MSW) can be transformed by a variety of biological and thermal processes. The most commonly used biological transformation process is aerobic composting. The most commonly used thermal transformation process is incineration. Waste transformation is undertaken to reduce the volume, weight, size or toxicity of waste without resource recovery. Transformation may be done by a variety of mechanical (eg shredding), thermal (e.g. incineration without energy recovery) or chemical (e.g. encapsulation) techniques.

C. DISPOSAL OF SOLID WASTE

The last stage in the solid waste management system is disposal of waste. Today the disposal of wastes by landfilling or uncontrolled dumping is the ultimate fate of all solid wastes, whether they are residential wastes collected and transported directly to a site which is useful for landfill, residual materials which is obtained by MRFs, residue obtained after combustion of solid waste, rejects of composting, or other substances from various solid waste-processing facilities. A municipal solid waste landfill plant is an engineered facility used for disposing of solid wastes on land or within the earth's mantle without creating nuisance or hazard to public health or safety, such as breeding of rodents and insects and contamination of groundwater.

III. BASIC TECHNIQUES OF ENERGY RECOVERY FROM MSW

Municipal Solid Waste (MSW) contains organic as well as inorganic matter. The latent energy present in its organic fraction can be recovered for gainful utilisation through adoption of suitable Waste Processing and Treatment technologies. The recovery of energy from wastes also have following benefits are as under,
(1) The total quantity of waste may be reduced to 60% to 90%, mainly depending upon the waste composition and the adopted technology;
(2) Demand for land, which is already scarce in cities, for landfilling is reduced;
(3) The cost of transportation of waste to far-away landfill sites also gets reduced proportionately; and
(4) Net reduction in environmental pollution. It is, therefore, only logical that, while every effort should be made in the first place to minimise generation of waste materials and to recycle and reuse them to the extent feasible, the option of Energy Recovery from Wastes be also duly examined. Wherever feasible, this option should be incorporated in the over-all scheme of Waste Management.

A. ANAEROBIC DIGESTION (AD)

In this process, also referred to as bio-methanation, the organic fraction of wastes is segregated and fed to a closed container (biogas digester) where, under anaerobic conditions, the organic wastes undergo bio-degradation producing methane-rich biogas and effluent/ sludge. The biogas production ranges from 50- 150m3/tonne of wastes, depending upon the composition of waste. The biogas can be utilised either for cooking/ heating applications, or through dual fuel or gas engines or gas / steam turbines for generating motive power or electricity. The sludge from anaerobic digestion, after stabilisation, can be used as a soil conditioner, or even sold as manure depending upon its composition, which is determined mainly by the composition of the input waste. Fundamentally, the anaerobic digestion process can be divided into three stages with three distinct physiological groups of micro-organisms:

Stage I: It involves the fermentative bacteria, which include anaerobic and facultative micro-organisms. Complex organic materials, carbohydrates, proteins and lipids are hydrolyzed and fermented into fatty acids, alcohol, carbon dioxide, hydrogen, ammonia and sulfides.

Stage II: In this stage the acetogenic bacteria consume these primary products and produce hydrogen, carbon dioxide and acetic acid.

Stage III: It utilizes two distinct types of methanogenic bacteria. The first reduces carbon dioxide to methane, and the second decarboxylates acetic acid to methane and carbon dioxide.

Factors, which influence the Anaerobic Digestion process, are temperature, pH (Hydrogen Ion Concentration), nutrient concentration, loading rate, toxic compounds and mixing. For start-up a good innoculum such as digested sludge is required. A temperature of about 35-380C is generally considered optimal in mesophilic zone (20-450C) and higher gas production can be obtained under thermophillic temperature in the range of 45-600C. Provision of appropriate heating arrangements and insulation may become necessary in some parts of the country.

B. *LANDFILL GAS RECOVERY*

The waste deposited in a landfill site it is a matter of subject over a period of time, to anaerobic conditions and its organic fraction gets slowly volatilized and decomposed according to the process similar to that taking place in an Anaerobic Digestion system as detailed in the previous section. This leads to production of landfill gas containing about 45-55% methane, which can be recovered through a network of gas collection pipes and utilized as a source of energy. In this method production of gas from landfill site starts in few months after disposal of the wastes at that sites and generally lasts for about ten years or even more depending upon mainly the composition of wastes and availability / distribution of moisture. The yearly gas production rates observed in full size sanitary Landfills in other countries range from 5-40 litre/kilogram. The MSW generated in major Indian cities is rich in organic matter and has the potential to generate about 15-25 l/kg of gas per year over its operative period.

C. *INCINERATION*

It is the process of direct burning of wastes in the presence of excess air (oxygen) at temperatures of about 8000° C and above, liberating heat energy, inert gases and ash. Net energy yield in incineration mainly depends upon the density and composition of the waste material, and relative percentage of moisture and inert materials, which add to the heat loss; ignition temperature; size and shape of the constituents; design of the combustion system (fixed bed/ fluid bed), etc. In practice, about 65 to 80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilized either for direct thermal applications, or for producing power via steam turbine generators (with typical conversion efficiency of about 30%). The combustion temperatures of conventional incinerators fuelled only by wastes are about 760° C in the furnace, , and in excess of 870°C in the secondary combustion chamber. These temperatures are needed to avoid odour from incomplete combustion but are insufficient to burn or even melt glass. To avoid the deficiencies of conventional incinerators, some modern incinerators utilise higher temperatures of up to 1650° C using supplementary fuel. These reduce waste volume by 97% and convert metal and glass to ash.

D. PYROLYSIS/ GASIFICATION

Pyrolysis is also refered to as destructive distillation or carbonization. It is the process of thermal decomposition of organic matter at high temperature (about 9000°C) in an inert (oxygen deficient) atmosphere or vacuum, producing a mixture of combustible Carbon Monoxide, Methane, Hydrogen, Ethane [CO, CH_4, H_2, C_2H_6] and non-combustible Carbon Dioxide, water, Nitrogen [CO_2, H_2O, N_2] gases, pyroligenous liquid, chemicals and charcoal. The pyroligenous liquid has high heat value and is a feasible substitute of industrial fuel oil. Amount of each end-product depends on the chemical composition of the organic matter and operating conditions. Quantity and chemical composition of each product changes with pyrolysis temperature, residence time, pressure, feed stock and other variables.

Gasification involves thermal decomposition of organic matter at high temperatures in presence of limited amounts of air/ oxygen, producing mainly a mixture of combustible and non-combustible gas (carbon Monoxide, Hydrogen and Carbon Dioxide). This process is similar to Pyrolysis, involving some secondary/ different high temperature (>1000°C) chemistry which improves the heating value of gaseous output and increases the gaseous yield (mainly combustible gases $CO+H_2$) and lesser quantity of other residues. The gas can be cooled, cleaned and then utilized in IC engines to generate electricity.

IV. COMPOSITION TEST ON PIRANA LANDFILL SITE

Methodology accepted for sample collection from Pirana landfill site is based on method of sample collection which is suggested by CPHEEO (SWM) manual. About 10 kg of (MSW) Municipal Solid Waste was collected from 20 points. Thus from each point like residential waste, commercial waste, garden waste, hotel waste, animal waste, institutional waste, street sweeping waste etc. of two samples were collected. Hence, 20 samples were collected from the solid waste heap having total quantum of 200 kg. The total quantity of waste so collected was thoroughly mixed. Then reduced by method of quartering up to 50 kg. The sample weighting 5 kg collected by this methodology was double bagged in plastic bags sealed and sent it to Gujarat laboratory for chemical testing. The results of composition results are shown below in fig. 1. Also the test results from Gujarat laboratory as shown in table 2.

Thermo chemical conversion techniques will be feasible for the Ahmedabad Municipal waste as it fullfill the following criteria:

- Moisture content (23.55%) < 45%
- Total Inerts (30.37%) < 35%
- Calorific value (3874) > 1200 Kcal/kg
- Organic matter (69.63%) > 40%

V. FIGURES AND TABLES

Population range (million)	Number of cities surveyed	Paper (%)	Rubber, Leather and Synthetics (%)	Glass (%)	Metals (%)	Total compostable matter (%)	Inert (%)
0.1 to 0.5	12	2.91	0.78	0.56	0.33	44.57	43.59
0.5 to 1.0	15	2.95	0.73	0.35	0.32	40.04	48.38
1.0 to 2.0	9	4.71	0.71	0.46	0.49	38.95	44.73
2.0 to 5.0	3	3.18	0.48	0.48	0.59	56.67	49.07
> 5	4	6.43	0.28	0.94	0.80	30.84	53.90

Table: 1 Physical Characteristics of a typical city Municipal Solid Waste

Sr.No.	Test Parameter	Result
1	Bulk density (gm/ml)	0.8419
2	Moisture %	23.54
3	Gross calorific value (Kcal/kg)	3874
4	PH (5% solution)	4.81
5	Total nitrogen %	0.91
6	Total organic carbon	43.52
7	C:N ratio	47:1
8	Protein %	5.68
9	Fiber %	2.32
10	Ash %	1.43

Table: 2 Tests Results of Gujarat Laboratory Physical of a typical city Municipal Solid Waste

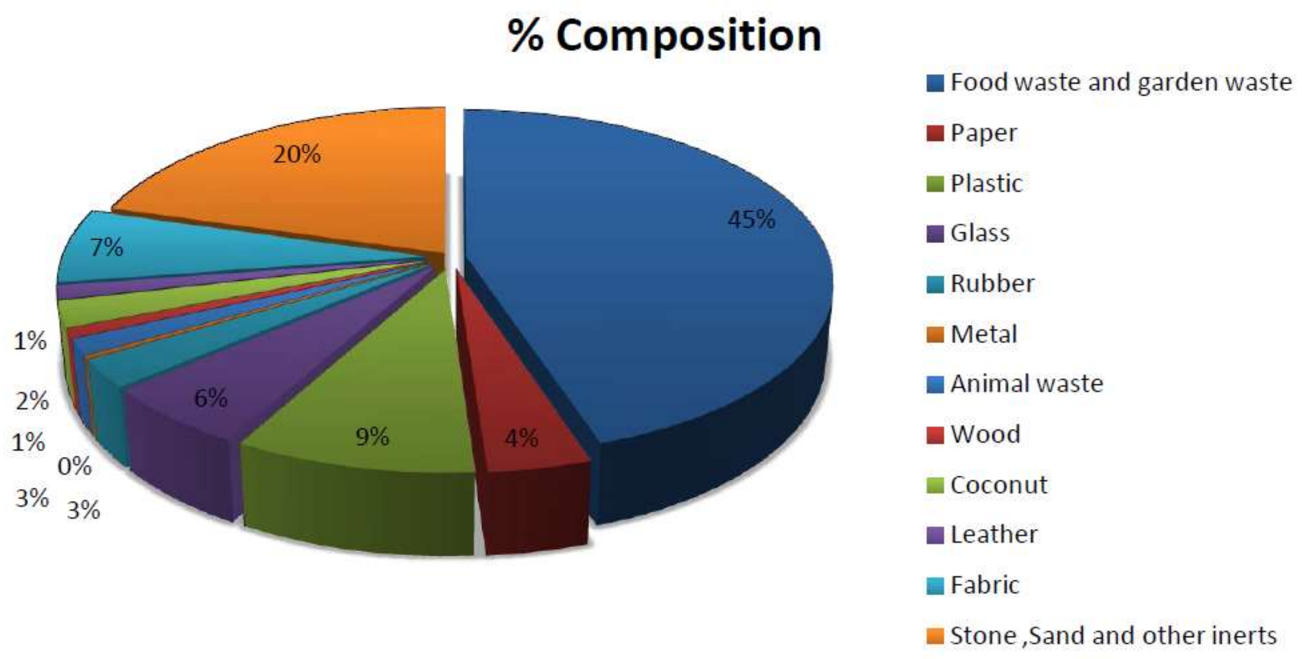

Fig. 1 Composition of MSW

VI. CONCLUSION

For Ahmadabad Municipal Solid Waste thermo-chemical conversion technique is more feasible. By addition of sewage sludge and certain changes in the composition it can be used for bio- chemical conversion technique. Segregation of waste at source should be promoted by the authority and NGO support. Instead of dumping waste residue inerts in the landfill it can be separated by gravity separators. From which recyables can be recycled and sand stones can be dumped into Sabarmati river.

ACKNOWLEDGMENT

I acknowledge my this article to my family members and my students who inspire me and encourage me as and when required for any new research work.

REFERENCES

[1] Bhattacharyya JK, Shekdar AV, Gaikwad SA. Recyclability of some major industrial solid wastes. Journal of Indian Association for Environmental Mangement 2004;31:71–5

[2] Yoshizawa S, Tanaka M, Shekdar AV. Global trends in waste generation. In: Gaballah I, Mishar B, Solozabal R, Tanaka M, editors. Recycling, waste treatment and clean technology. Spain: TMS Mineral, Metals and Materials publishers; 2004. p. 1541–52 (II).

[3] M.R. Alavi Moghadam a,*, N. Mokhtarani b, B. Mokhtarani, Municipal solid waste management in Rasht City, Iran, Waste Management 29 (2009) 485–489

[4] Metin, E., Eröztürk, A., Neyim, C., 2003. Solid waste management practices andreview of recovery and recycling operations in Turkey. Waste Management 23 (5), 425–432.

[5] Shekdar, A.V., Tanaka, M., 2004. Integrated Approach for Sustainable Solid Waste Management in Some Asian Countries, CD-ROM of ISWA 2004 World Congress, October 17–21, Rome, Italy.

[6] WHO (World Health Organisation), 2010c. Health Care Waste Management. Washington, DC, USA. http://healthcarewaste.org.en.115_overview.html (accessed 01.10.10).

[7] C.P.H.E.E.O manual on solid waste management-2000

[8] Municipal solid waste handling and management rules 2000

[9] Final project submission to L.J. eng, college , Ahmedabad, India by the students of Civil Engg 1. Krupali d raval
2. Priyanka r deliwala