Combined mechanical-biological treatment as a green technology for energy recovery from municipal solid waste

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COMBINED MECHANICAL-BIOLOGICAL TREATMENT AS A GREEN TECHNOLOGY FOR ENERGY RECOVERY FROM MUNICIPAL SOLID WASTE

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ABSTRACT

Energy plays a pivotal role in the development of any nation. The energy crisis and environmental degradation are currently two vibrant issues for global sustainable development. The limited reserves and environmental hazards of fossil fuels have led the world in the field of renewable energy sources. Municipal solid waste [MSW] is gaining central importance in recent years due to the rapid urbanization in India without any prejudice on waste disposal has led to several serious issues and concerns. The MSWM [Municipal Solid Waste Management] system comprises the generation, storage, collection, transfer and transport, processing and disposal of solid wastes. Most of the waste generated in India is either retained in open or dumped in landfills with no prior treatment before dumping. Going on either way will lead to the loss of energy quanta's in the form of waste. Rather it should be considered as the source of energy as it contains organic matter like cellulose, glucose and so on. This paper made an attempt to discuss the various possible energy recovery ways from MSW along with a particular emphasis on emerging technique such as Mechanical Biological Treatment (MBT) which is the perfect blend of biological and mechanical process of treating municipal waste with number of engineering principles to lessen the dependence on biological processes that are relatively slow as well as on mechanical processes that involves the usage of excessive energy.

Keywords**:** Municipal Solid waste, Bio stabilization, Sustainable development; Waste to Energy, Mechanical-Biological Treatment.

1. INTRODUCTION

The exponential growth of human population with rapid urbanization aligned with global living standards have attributed to escalating the quantity and diversity of wastes generated by various activities. Broadly, solid waste can be classified as urban waste, industrial waste, biomass waste and medical waste. In general, urban waste includes waste from households and commercial activities, often referred to as Municipal Solid Waste (MSW). It consists of household waste, construction and demolition debris, sanitation residue, waste from streets and so forth generated in municipal or notified areas in either solid or semi-solid form. The essential thing is that it comprises the elements generated from daily household chores, kitchen wastes, market products related to furniture, torn clothes and so on. The wide distinction in the composition of MSW is due to the fact on their strategic locations and their lifestyles. For instance, if MSW collected from an area comprises semi-urban or rural areas, then the waste is likely to be with biodegradable items, whilst a municipality covering an area of a metro city would flooded with ample plastic and synthetic waste.

Industrial waste constitutes of solid, semi-solid, liquid or gaseous or residual materials (excludes hazardous or biodegradable wastes from industrial operations). Biomass waste is defined as biomass by- products, residues and waste streams from agriculture, forestry and related industries. Medical waste comprises waste generated at health care facilities, such as hospitals, blood banks as well as medical research facilities and labs. The prime focus of this paper is on MSW and the possible ways to derive energy out of it, which is the current emerging arena in Waste to Energy (WTE) technologies. Discussions on other types of wastes is beyond the scope of this paper.

Each and everything that we are utilizing in our day to day life is having some energy content that reveals that even the waste that which we generate after consumption, still contains a decent amount of energy. This strategy could be easily understood by the law of conservation of energy which states that energy can be neither created nor destroyed but can change from one form to other. Though several techniques have been developed for waste management, yet, a huge quantum of MSW goes directly as landfill that further leads to the accumulation of hazardous chemicals in the soil environment with slow decomposition of biodegradable solid waste. This direct setting of waste into landfill also contributes to global warming through the emission of greenhouse gases (GHG). All these aspects is just favoring the need of a new technology that will neither take too much time as our country is populating at a very fast rate, nor too much energy requirement as we are developing nation still facing energy crisis. This is the time of urgency of this revolutionary approach to building a nation on sustainable grounds.

2. MSW TREATMENT TECHNOLOGIES

The overall various treatment technologies for solid waste has been depicted in Fig. 1. Disposal of waste in a landfill involves burying the waste and this remains a common practice in most of the developing countries. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. The organic matter in solid wastes in developing countries is much higher than that in developed countries. Hence an obvious route of converting this organic matter to useful products exists. Now landfill is the disposal of waste into or onto land. Today, landfill sites are constructed and operated to strict technical standards to reduce environmental effects. In reality, most of disposal sites lacked appropriate fencing and waste picking is commonly practiced, posing problems for the controlled operation of the sites.

Actual landfilling requires the waste to be weighed and checked to ensure it is compliant with its landfill operating permit. It is then tipped into the landfill, compacted and covered to prevent odor, litter, and pest infestations. Microbes will gradually decompose the waste. This decomposition process, mixed with rainwater creates leachates and gas, which are both taken out of the landfill through a system of pipes. The leachates are then usually taken for treatment, while the gas, mainly a mix of carbon dioxide and methane, may be burnt off or used in an on-site energy generation plant that contributes energy to the national grid. When a landfill has reached its maximum capacity it is covered completely with an engineered cap, e.g. using clay and restored using soils or other covering materials so that the site can be utilized in the future for agriculture, amenities or nature conservation.

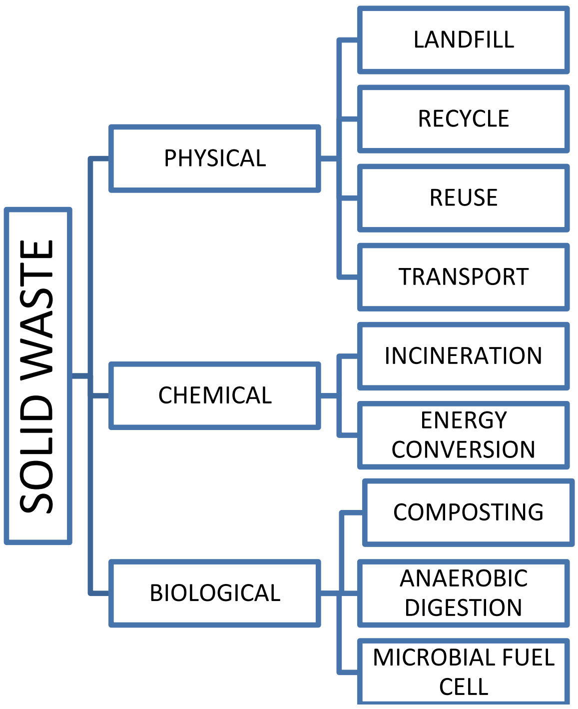

Fig. 1: Various treatment technologies for municipal solid waste

Recycling is a process to change waste materials into new products to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce pollution by reducing the need for "conventional" waste disposal, and lower greenhouse gas emissions as compared to plastic production. Recycling is a key component of modern waste reduction and is the third element of the "Reduce, Reuse and Recycle" waste hierarchy. Recycling can help in generation of new products from materials from which the waste material is originally made.

Firstly separation of waste to wet and dry components in separate containers is necessary for recycling. Sometimes the recyclable materials are placed in a single bin for collection, and the sorting is handled later at a central facility. Recyclable materials include many kinds of glass, paper, metal, plastic, textiles, and electronics. Certain other recyclable materials include office paper, white paper, colored paper newspaper (bags and strings removed), magazines (all types), catalogs (all kinds), phonebooks (all kinds) junk mail ,paperboard, tissue boxes, heavyweight folders, paper towel and toilet paper rolls,food packaging (un-waxed), shredded paper, paper milk, juice and soy milk cartons, books, all soft cover, and hardcovers, metal and tin beverage containers, metal and tin food containers, aluminum foil, etc. The quality of recyclates is recognized as one of the main challenges that needs to address to develop a greener economy.

3. TECHNOLOGICAL ROUTES FOR MSW TO ENERGY

Energy can be recovered from the organic fraction of waste (biodegradable as well as non- biodegradable) through thermo-chemical and biochemical methods. The pathways illustrating the primary MSW to energy technologies are highlighted in the Fig. 2.

There are various techniques such as biomethanation, mass burn incineration, refuse derived fuel plants, gasification and pyrolysis and plasma arc gasification are followed for conversion of waste to energy and widespread researches have been carried out to estimate the energy generation potential for the different techniques. Incineration of RDF pellets for power generation and biomethanation are currently the preferred technologies for MSW to energy in India. Some emerging technologies such as fermentation, plasma pyrolysis, microwave waste destruction and laser waste destruction exist and are at various stages of commercial uptake. These merit a continuing review to assess their relevance for possible application to the treatment of specific waste types under Indian conditions.

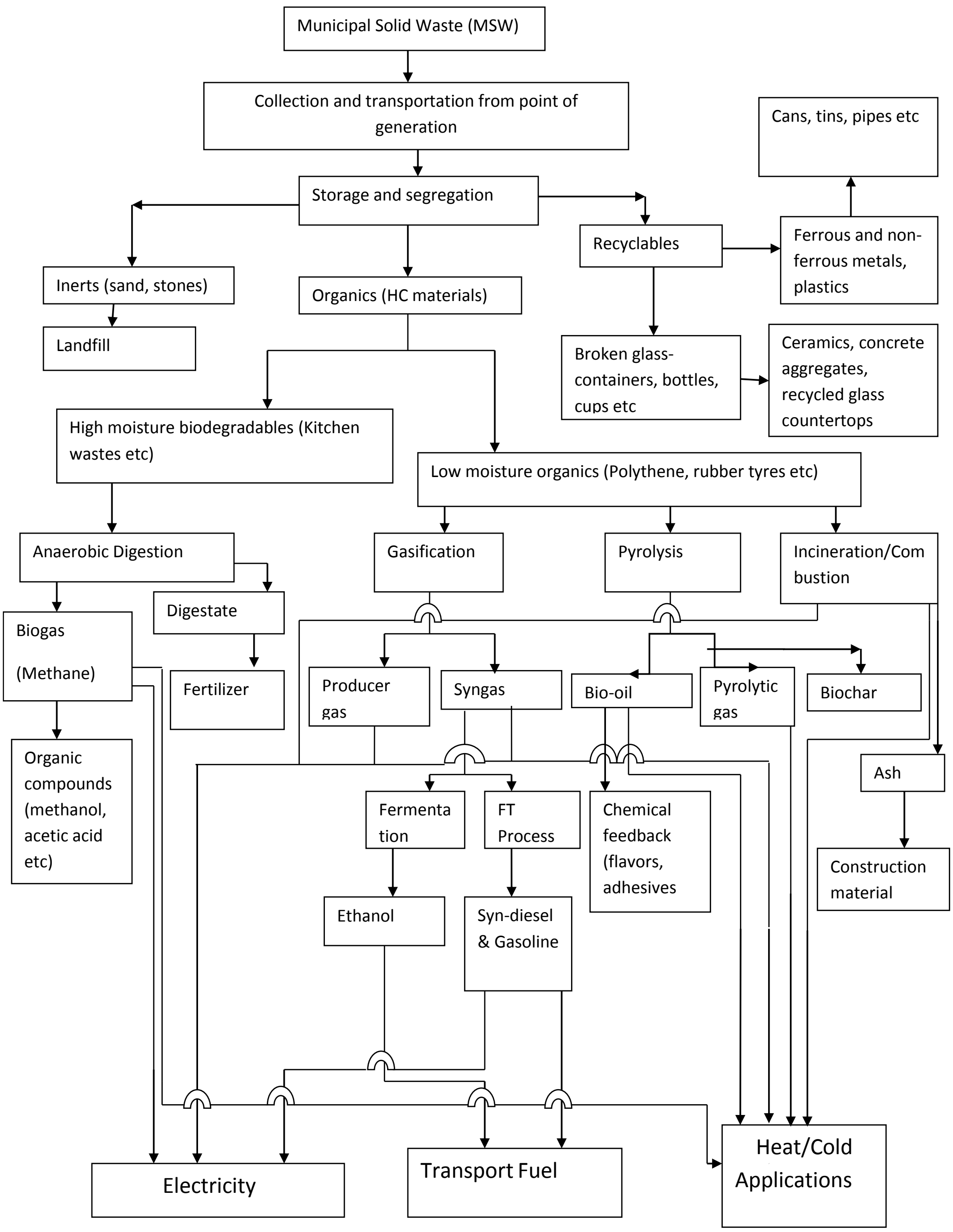

Fig. 2: Various technological routes to convert MSW to energy

4. MECHANICAL BIOLOGICAL TREATMENT

The implementation of mechanical, and biological treatment includes some preliminary steps;

- Separate collection of municipal waste
- Separate collection of infectious and hazardous waste
- Mixed municipal waste
- Bulky municipal waste
- Construction and demolition waste
- Green waste
- Materials for Recycling
- Food and kitchen waste

Now depending upon the different waste, various types of approaches are undertaken to deal with it.

4.1 Biostabilisation

Every city of India, being in developing country, is suffering from a severe problem of maintaining the municipal waste as we are not concerned much about harnessing energy from the MSW. Instead, we just dump it in open or set it into a pit. The rising urbanization is leading to increasing in MSW production, but the disposal sites are not increasing on the same time. The population is also increasing. Keeping all these facts and figures in minds we have to utilize the MSW in a sustainable and a useful manner. Setting the waste to landfill is an age old technology. It is now showing its side-effects also like leaching of harmful chemicals to groundwater, methane gas production, etc. All these things required biostability in treating the waste. The land area for disposal of these wastes is also limited too due to increasing urbanization. For this, we have to reduce the size of our waste produced. We have to decrease its volume. The quality of the waste needs to be improved for its further processing that could be done by increasing the energy density of the MSW. The enhanced quality waste, when treated to landfill, will remain stable and will have its lesser outcome as a leachate on the soil environment. This biostability is achieved by following the mechanical and biological process in a precise manner.

4.1.1 *Mechanical Treatment*

The goal of mechanical treatment is to encapsulate the energy in a small volume/mass to increase the energy density of the given solid waste. This pre-treatment process is of significant value. It governs the quality of the process. The following process such as shredding, screening, sorting and homogenization achieves this goal. However, higher the efficiency while going through these process, the more will be its impact on further biological pre-treatment of waste

4.1.2 *Biological Treatment*

After successful completion of Mechanical pre-treatment, the next stage is to set biological pre-treatment. The main aspects of the biological pre-treatment are the extraction of useful products from preprocessed material. This primarily deals with the treatment of organic composites to useful energy resources involving degradation. The main objective of the mechanical pre-treatment was a homogenization of the mixture based on size, nature, density, organic composites, and inorganic composites to ease the further processing. The overall result of this process is a less hazardous chemical waste that could be done with two processes namely 1). Aerobic degradation and 2). Anaerobic/Aerobic degradation: (i.e.) Fermentation to derive biogas.

After this mechanical and biological treatments, the mixture is again screened. After screening the processed material that is subjected for landfill and the remaining is again included either in degradation process or may be sent to some respective places according to its nature for further processing where it can be utilized more wisely.

4.2 Biodrying

These biodrying units are the source of solid recovered fuel (SRF). Although the general process used here is quite similar to the composting, the working of the system is totally different. Composite refers to the aerobic process that includes the role of micro-organisms in treating the waste produced. The decomposition of waste is promoted by biostimulating the local environment. The output here is “humus” like compost that can be applied safely as a fertilizer to the land. On the contrary, biodrying aims at developing a high-quality SRF. It includes treating of moisture content present in the waste material. The production of high-quality SRF is obtained by maximizing the energy content by removal of moisture present.

4.2.1 *Application: Drying*

This process as the name suggests a reduction in the moisture content of the solid waste. This is done to increase the quality of waste in terms of energy volume. The process is as follows:

- Evaporation involves the application of heat to vaporize the moisture content present in the solid waste.
- The airflow facilitates the removal of water vapor produced via exhaust and produces the dried output.

- Convective evaporation works as the force to pump the vaporized moisture out of the system.
- Biodegradation has a vital role in generating internal heat and serves the purpose of heat requirement for the system that later facilitates by convective mode of transfer.

4.2.2 *Internal Mechanism of Drying*

Removal of MC by convective phenomenon is governed by the thermodynamic equilibrium between the wet waste matrix (solid state) and the air flowing through the array. The adsorption/desorption isotherms help us in stabilizing a relationship between the relative humidity of air and Equilibrium moisture content of the waste. These are temperature dependent phenomenon making our system highly temperature sensitive. For specific drying, we have the specific shape of the sorption curve. Different regions of sorption isothermal curves correspond to drying involving moisture present in various states. Air convection will eradicate water from the surface and for further removal of interior water, the process is governed by a diffusion mechanism.

4.2.3 *Process Control*

- Matrix conditioning through mechanical pre-processing. e.g-mixing
- Type of containment of waste matrix that affects the post processing of the waste
- Use of mixing /agitation to homogenize it
- Aeration system design
- Process control for air low rate
- Systems for controlling the other parameters and
- Residence time within the reactor

This process of producing the dry fuel is called RDF (Refuse-derived fuel). It can be used as a source of energy along with other energy sources. In European nations, it is employed in WTE technology. We derived two kinds of fuel using this technology of biodrying. One is RDF, and other is SRF. The line of distinction between these two is blurred, but one thing is sure that SRF preparation is more complex than RDF preparation. Production of RDF involves the screening of larger combustible fractions but in RDF technique similar step like this also involved biodrying.

5. SUMMARY

Indian MSW is a heterogeneous mix of combustibles along with organic matter and relatively high moisture content. The selection of treatment technology for MSW depends upon the quantity and quality of waste to be treated after considering the local treatment site conditions. This highly stressed the importance of source segregated waste, which is dedicated to nature, the selection of appropriate technology is relatively tranquil and its performance, victory could be easily assured. Therefore, it is highly desirable to have solid waste segregated at source, which is also mandatory as per the MSW Rules, 2000. Also, no biodegradable material should be deposited in a sanitary landfill. Hence, there is almost nil scope of biogas generation in the form of landfill gas from new sanitary landfills. Therefore, the energy generation through biochemical conversion or combustion would be the next best available solution for the sustainable solid waste management. Further mechanical biological treatment technologies offers several key advantages in waste to energy sectors as follows: Biogas could be generated as per subjection to anaerobic digestion, energy rich solid recovered fuel or refuse-derived fuel to be used in wide range of thermal processes such as pyrolysis and gasification techniques. In addition to routine energy routes, several other value-added products could also be achieved: residues like secondary aggregates could be used in construction sites, production of compost like outputs could be used in land applications. Recently, Government of India has sanctioned the five pilot projects in the year 2012, for energy recovery from MSW in accordance with the decision of Honourable Supreme Court given during a hearing held on May 15, 2007 is a good start and sign for the sustainable solid waste management.

REFERENCES

1. Adam Lead and Andrew Godley, How green is the mechanical biological treatment, An article in Waste Management World.
2. http://www.waste-management world.com/articles/print/volume-12/issue-2/features/how-green-is-mechanical-biological-treatment.html (Accessed on Feb, 14, 2015).
3. Dimpal Vij, (2012) Urbanization and solid waste management in India: Present practices and future challenges, Procedia - Social and Behavioral Sciences 37, 437 – 447.
4. Sharholy, M., K. Ahmad, G. Mahmood, R.C. Trivedi, (2008), Municipal solid waste management in Indian cities. A review, Journal of Waste Management, 28 pp. 459–467
5. Saini, S., Prakash Rao, Yogesh Patil (2012), City based analysis of MSW to energy generation in India, calculation of state-wise potential and tariff comparison with EU, Procedia - Social and Behavioral Sciences 37, 407 – 416.
6. Velis, C.A., P.J Longhurst, G.H. Drew, R Smith, and S.J.T Pollard (2009), Biodrying for the mechanical-biological treatment of wastes: a review of process science and engineering, Bioresources Technology, 100(11), 2747-2761.
7. Vishwanathan, C., (2010), Mechanical Biological Pre-Treatment of solid waste prior to landfill.
8. Municipal Solid Wastes (Management and Handling) Rules, (2000), Ministry of Environment & Forest, Schedule II & IV, Government of India.