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Municipal Solid Waste a Potential Bioenergy Source: A brief review

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ABSTRACT

The rapid expansion of industry, urbanization and growing population are major factors for increased quantity of Municipal Solid Waste (MSW) generation. MSW holds the greatest potential as source of bioenergy. The management of solid waste and valorization is based on an understanding of MSW composition and physicochemical characteristics. However, issues related to environmentally sound MSW management-including waste reduction and clearance-have not been addressed sufficiently. This study presents an overview on MSW that can be used as a source of bioenergy and current technological scenario to generate energy from MSW.

Key Words: MSW, Bio-energy, Waste Reduction, Biogas, Energy Recovery, Landfilling

I. INTRODUCTION

The composition of municipal waste varies greatly from country to country and changes significantly with time [1]. In developed countries without significant recycling, the MSW predominantly comprises of food wastes, yard wastes, containers and product packaging, and other miscellaneous wastes. Much of what we throw away contains recoverable energy. Paper and card, wood, cloth, food waste and plastics are the main potential energy sources in domestic waste [2]. Most of the rest consists of glass, metals and miscellaneous rubble. In the UK and elsewhere, domestic waste is typically disposed of by tipping it into large landfill sites without proper treatment. Sometimes the waste is incinerated first and only the remaining ash and non-combustible material are disposed off into the landfills. Increasingly, a proportion of the waste is being separated for recycling at some stage along the way. It is possible to recover energy from landfill sites and from waste [3]. Domestic waste could also provide feed stock for a number of other conversion systems, all of which could recover useful energy while reducing the requirement for landfill sites. However, whatever the energy technology, domestic waste is a low grade fuel. Its consistency is variable and not well suited to mechanical handling systems; the proportions of the various constituents will vary from load to load; the moisture content and heating value will vary; and the proportion of non-combustible material will keep the heating value low [4]. All of this can lead to inefficient combustion if the process is not well controlled, making it more difficult to control toxic emissions from plastics and other materials [2]. There is also a potential conflict between the recycling of materials and the recovery of energy from those materials. The main benefit of domestic waste as a fuel source is that, as with most other waste streams, energy technology can reduce the waste disposal problem [5]. 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 [6].

II. BASIC TECHNIQUES OF ENERGY RECOVERY

The Thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content [3]. 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 option under this category is Anaerobic Digestion, also referred to as Biomethanation [8].

III. LANDFILLING AND LFG RECOVERY

Landfill gas (LFG) is a by-product of decomposition of MSW. Plenty of project developers started hunting for landfill sites to develop landfill gas recovery projects. Most of the sites in Asia were of open dump type. However, recently engineered landfill sites have been prepared for MSW waste disposal and collection of LFG [3]. LFG production depends upon the waste composition, weather condition and landfill management. For good LFG generation, the amount of waste dumped should be greater than 1 million tonne in a site with a depth of more than 10 m, preferably without any major fire accident [2]. The landfill gas can be recovered using a network of perforated gas collection pipes and the gas can be used for power generation [8].

The production of LFG starts in a landfill site within a few months of waste disposal and lasts for about 10 years or more depending upon the composition of waste, its availability and moisture content [2]. Generally, depth of the landfill gas well is 80% of the height of the landfill. The gas is usually pumped out using a blower and the moisture is removed in the moisture trap and then cleaned using SO_2 scrubber before passing it to the engine, to produce electricity [9].

IV. MSW TO BIOGAS

MSW to biogas is one of the new concepts in the management of MSW. Developed countries have taken the lead to treat the bio-degradable MSW through anaerobic digestion. The sludge from anaerobic digestion can be sold as manure. Other major advantage of MSW to biogas is the reduced land requirement. Compared to landfill, the size of MSW biogas plant is very small [9].

This approach involves segregation of biodegradable waste such as vegetable wastes, food wastes, etc. from MSW and using it in a biogas reactor to produce biogas. In a typical Asian city such as Beijing, Mumbai, Bangkok, etc., organic material accounts for 80% of the MSW. The net biogas production ranges from 100-120 m^3 per tonne of organic MSW and the compost generation is around 500 kg. Some of the cities like Singapore, Bangkok and Chennai have modern power plants operating with biogas generated from MSW [4].

V. 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 [7]. The biogas production ranges from 50-150m^3/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 [3]. 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.

VI. INCINERATION

Incineration involves the combustion of Municipal Solid Waste (MSW) without any pre-treatment (also called mass burning). Mass burning has been in practice in developed countries for more than 100 years. More than 600 mass burning plants are in operation around the world.

Volume reduction of MSW for about 90% is possible with incineration plants, thereby resulting in considerable reduction in land required for disposing the 90% MSW [3]. In MSW mass burn system there is no pre-treatment except the removal of visible bulk items. However, some of the wastes such as construction debris, earth, concrete, stones, chemical waste, explosive or highly flammable waste, carbon fibres, insulation materials, Polyvinyl Chloride (PVC) etc., are not suitable for mass burn. It is also advisable to separate the biodegradable wastes from MSW to use in digesters so that the biogas from the digester can be used to generate power using gas engines [10]. Only few countries in Asia have a long history of proper management of MSW using incineration power plants. As of now, there are 4 power plants of sizes ranging from 30 MW to 80 MW are in operation (for more than 25 years) in Singapore and one more plant is under commissioning. A 2.5 MW incineration plant is in operation in Phuket, Thailand. For the mass burn facilities, the minimum calorific value requirement is 7 MJ/kg on an annual average basis. The moisture content and percentage combustible are also important parameters in MSW mass burn technologies [6]. The investment cost and annual O&M costs for MSW based power plants are much higher than biomass projects. SOx, NOx, dioxin, heavy metals, HCl and air born particulates, fly ash and bottom ash are the pollutants from mass burn power plants. The devices/processes commonly used for effective removal of pollutants include electrostatic precipitators, fabric filters, scrubber & lime injection system and activated carbon injection system. With the use of modern technologies, it is also possible to minimize water pollution, odour and noise problems. It is also possible to recover ferrous metals from the ash which provides additional revenue. Japan, China, Korea and Taiwan too have implemented many incineration plants in the recent years. The potential for incineration plants in Asia is high. Among all MSW management systems, incineration to power is more popular in Asian cities because, it eliminates the need of land requirement for landfilling [11].

VII. INDIAN SCENARIO FOR ADOPTION OF INCINERATION TECHNOLOGY

All sorts of waste materials are generated in the Indian cities as in other countries. However, in the absence of a well-planned, scientific system of waste management (including waste segregation at source) and of any effective regulation and control of rag-picking, waste burning and waste recycling activity, the left-over waste at the dumping yards generally contains high percentage of inerts (>40%) and of puterscible organic matter (30-60%). It is common practice of adding the road sweepings to the dust bins. Papers and plastics are mostly picked up and only such fraction which is in an unrecoverable form remains in the refuse. Paper normally constitutes 3-7% of refuse while the plastic, content is normally less than 1% [9]. The calorific value on dry weight basis (High Calorific Value) varies between 800-1100 Kcal/Kg. Self-sustaining combustion cannot be obtained for such waste and auxiliary fuel will be required. Incineration, therefore, has not been preferred in India so far. The only incineration plant installed in the country at Timarpur, Delhi way back in the year 1990 has been lying inoperative due to mismatch between the available waste quality and plant design. However, with the growing problems of waste management in the urban areas and the increasing awareness about the ill effects of the existing waste management practices on the public heath, the urgent need for improving the overall waste management system and adoption of advanced, scientific methods of waste disposal, including incineration, is imperative [4].

VIII. RDF COMBUSTION

Refuse Derived Fuel (RDF) is a method of pre-processing the waste in order to use it as a fuel in boilers. This technology involves various processes to improve physical and chemical properties of solid waste. Basically, RDF systems are used to recover recyclable materials and to separate MSW into combustible and non-combustible fractions. The combustible material is called RDF and can be used in boilers. Typically, the volume of waste is reduced to 20 to 30%. RDF has a higher calorific value when compared to that of MSW. Waste sorting includes primary and secondary trommel screens which mechanically separate the dry fraction from the organic one, magnetic and induction-type separators for metals recovery, a glass recovery system and a shredder. Due to reduction in fuel particle size and reduction in non-combustible material, RDF fuels are more homogeneous and easier to burn when compared to the MSW feedstock. Emission characteristics of RDF are superior due to less NO_X, SO_X, CO and CO_2. The advantage of the refuse-derived fuel plant type is the relatively higher energy content of the RDF fuel [11].

Several RDF plants are in various stages of implementation in Asia. In India, an RDF fired MSW plant is in operation for quite a few years.

IX. GASIFICATION

Gasification is already a proven method for homogenous organic matter like wood, pulp etc. and is now being recognised as an attractive option for MSW also. In these processes, besides net energy recovery, proper destruction of the waste is also ensured [10]. The products are easy to store and handle. These processes are therefore being increasingly favoured in place of incineration [12].

X. CONVERSION TECHNOLOGIES FOR BIOFUEL

Conversion of biomass into ethanol and biodiesel liquid fuels has been increasing steadily over the past decade. As of November 2008, there are 180 fuel ethanol production facilities in operation or expansion and another 23 under construction. Total fuel ethanol production in 2008 was 9 billion gallons (RFA, 2009). In addition, as of January 2008, 171 companies have invested in development of biodiesel manufacturing plants and were actively marketing biodiesel. The annual production capacity from these biodiesel plants is 2.24 billion gallons per year (National Biodiesel Board). This discussion focuses on ethanol and biodiesel production; however, other biofuels can also be produced, such as methanol, butanol, synfuels, and algal fuel. Additional details about current and developing technologies for converting solid biomass into liquid fuels are available from the Western Governors' 2008 Association Strategic Assessment of Bioenergy Development in the West, *Bioenergy Conversion Technology Characteristics.* Both ethanol and biodiesel can be produced using a variety of feedstocks and processes.

XI. CONCLUSION

The different technologies for recovering useful energy from Municipal Solid Wastes already exist and are being extensively utilised in different countries for their multiple benefits. A detailed feasibility study needs to be conducted in each case, duly taking into account the available waste quantities and characteristics and the local conditions as well as relative assessment of the different waste disposal options. The Waste-to-Energy facilities, when set up with such consideration, can effectively bridge the gap between waste recycling, composting and landfilling, for tackling the increasing problems of waste disposal in the urban areas, in an environmentally benign manner, besides augmenting power generation in the country.

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