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Review

A review on organic waste to energy systems in India

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ABSTRACT

Waste generation is increasing day-by-day with the growth of population which directly affects the environment and economy. Organic municipal solid waste (MSW) and agriculture sectors contribute towards maximum waste generation in India. Thus, management of organic waste is very much essential with the increasing demand for energy. The present paper mainly focusses on reviewing waste to energy (WtE) potentials, its technologies, and the associated challenges. Different substrates are utilized through various technological options in India. Organic waste has good potential to attain sustainable energy yields with and without affecting the environment. A realistic scenario of WtE technologies and their challenges in line with the existing Indian condition is presented in this paper.

1. Introduction

Developing countries are facing soaring challenges of managing solid waste and its improper management causes hazards to society and the environment. The high organic waste fractions in the solid waste can lead to the recovery of energy by applying appropriate processing options but on the other side, it can create pollution problem if it is disposed off without adopting any control measures. The most common treatment and disposal options for municipal solid waste (MSW) are composting, mechanical & biological treatment, recycling, waste to energy (WtE) and landfilling (Psomopoulos et al., 2009).

According to the Ministry of New and Renewable Energy, Govt. of India (Mazumdar, 2013), 1700 MW of energy will be generated from urban organic solid waste (1500 from MSW and 225 MW from sewage) along with 1300 MW of energy from industrial waste (http://www.eai.in/ref/ae/wte/wte.html).

There are various WtE systems, such as anaerobic digestion (AD) of organic waste, combustion, pyrolysis, gasification and incineration. In India, the organic waste fraction varies between 40 and 60% of the total solid waste streams. These waste fractions can be utilized through various treatment options, such as composting as organic fertilizer and soil enhancement as well as AD for biogas production. The calorific value of urban solid waste is 7.3 MJ/kg, and the moisture content is around 47% (Annepu, 2012). "To encourage the AD technology from organic waste, the Government of India has set-up 1 million family-sized plants and hundreds of community plants during the 6th five-year plan period" (Abbasi, 2012). The thrust was continued up to the 11th five-year plan, and till date, close to four million biogas plants have been installed in India (Abbasi, 2012). The scale for the growth of Indian economy during 1947–2017 was measured through Five-Year Plan by the Planning Commission (1951–2014) (http://planningcommission.gov.in/index_oldpc.php) and then the NITI Aayog (2014–2017) (http://niti.gov.in/). MNRE implemented the "National Biogas and Manure Management Programme (NBMMP) and National Biomass Cook-stoves Programme (NBCP)" in all the States and Union Territories (UTs) of India for setting up of family type biogas plants mainly for rural and semi-urban/households (Abbasi, 2012). There are challenges to maintain and operate biogas plants due to lack of skilled manpower. On the basis of a detailed review of literature and experiences of the authors, biogas technologies in India clustered by size, end-users, such as restaurants, communities and substrate inputs, like food, household and agricultural organic waste, and other factors contributing to its success and failure were reviewed and presented in this paper. The objective of the review is to identify the potential from the organic waste to energy conversion in India and its associated challenges.

2. Present energy demand in India and its future requirement

Energy requirement is the need of the hours and it is one of the most significant indicators for socio-economic development. The biomass energy from firewood, crop residues, animal dung etc. are still used in rural parts of developing countries like India to meet the energy requirement.

India had 17% of the world's population with highest population density *i.e.*, 382 persons per km^2 on an average (Census of India, 2011). Since, India is in the transition phase and likely to be categorized under

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Table 1
Energy balance of India for 2010–11 ($\times 10^6$ MW-h).

Sectors	Coal	Crude Oil	Oil Products	Natural Gas	Nuclear	Hydro	Solar-Wind and Others	Bio-fuels and Waste	Electricity	Total
Total primary energy supply	3400	2400	640	630	57	110	22	190	5.6	7454.6
Final consumption	980	–	1800	250	–	–	3.5	1910	730	5673.5
Industry Sector	890	–	3.6	760	–	–	–	331	240	2224.6
Transport	–	–	590	24	–	–	–	1.9	61	676.9
Residential	190	–	270	0.3	–	–	–	1510	156	2126.3
Non-energy use industry/ transformation	–	–	240	150	–	–	–	–	–	390

Source: Minde et al. (2014) & International Energy Statistic: Total Energy: Total Primary Energy Production.

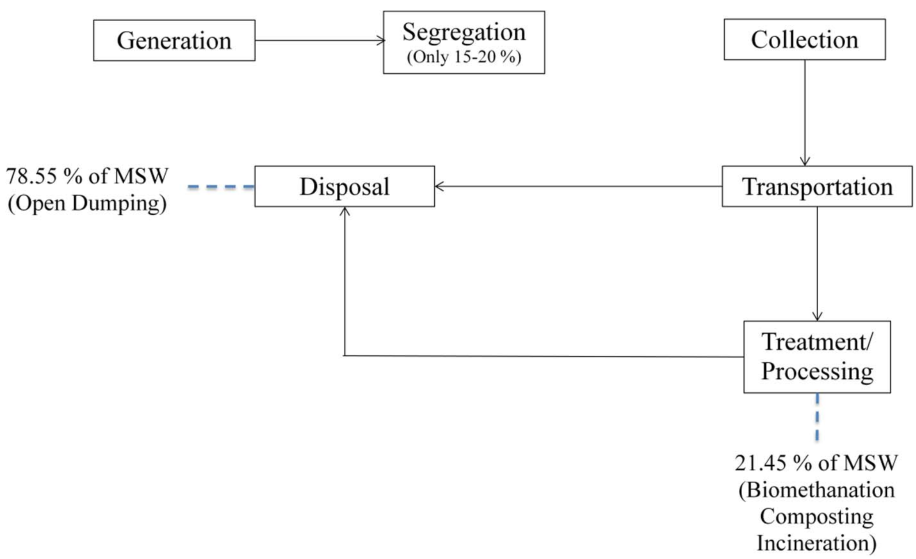

Fig. 1. Existing MSWM system in India.

developed country status and hence the energy enhancement is required both from non-renewable and renewable sources. The energy balance of India is presented in Table 1 which interprets the total primary energy supply by different energy sources and final energy consumption (Minde et al., 2014).

According to International Energy Statistics (2012), 288 million Indian population are still without electricity (International Energy Statistics, 2012). On an average, 75% are under electrification rate with urban and rural electrification rates as 94% and 67%, respectively in India (Minde et al., 2014; and World Energy Outlook, 2011). In India, 27% people rely on solid fuels for cooking, and 28% people have access to the electricity (UNDP, 2009). The traditional cookstoves with efficiency range 10–14% is still used which leads to insufficient cooking (Ravindranath and Hall, 1995). Biomass combustion with traditional cookstoves is the major cause of indoor air pollution in India. The incomplete combustion releases temperature entrap pollutants, such as methane (CH_4) and black carbon, which have higher global warming impact than carbon dioxide (CO_2) per unit of carbon emitted (Bond et al., 2004; Ramanathan and Carmichael, 2008).

To meet the energy requirement, India needs 3–4 times more energy than the total energy consumed today. The most economical benefits are to minimize environmental pollution and meeting the energy demand for various purposes. In India, the MNRE, Govt. of India initiated a National Master Plan in 1994, which incorporates biogas technology as one of the major WtE options to be developed and adopted in the country (http://www.mnre.gov.in/). The aim of the National Policy on Biofuels is mainstreaming of the biofuels and therefore envisages a major role for it in the energy and transportation sectors of the country in future. It will also bring the rapid development and will promote the cultivation, production and use of biofuels to substitute the fossil fuels for transport to be used in stationary and other applications, which will contribute towards the energy security and climate change mitigations. The goal of the policy is to ensure that a minimum level of biofuels can be used for the market to meet the demand (National Policy on Biofuels, MNRE, 2011). Now-a-days, renewable source accounts for 33% of India's primary energy consumptions. India is adopting renewable energy technologies and also taking initiatives towards reducing air pollution and ensuring a more sustainable development (Kumar et al., 2010).

3. Organic waste and its energy potential

3.1. Organic waste sources and its management in India

Different types of organic waste are available in India. In this paper, an organic waste stream is comprised of organic fraction of MSW (OFMSW), agriculture waste (AW), waste water, and animal dung.

Urbanization contributes enhanced MSW generation and its unscientific handling damages the environment causing health hazards. With the introduction of Solid Waste Rule, 2016 of the Ministry of Environment, Forest and Climate Change (MoEF & CC), the Ministry of Urban Development (MUD) aimed to guide all urban areas in the country towards achieving sustainable municipal solid waste management (MSWM) system adopting the principle of waste minimization at source based on 3R principles, such as reduce, reuse and recycle with proper systems of collection, segregation, processing, transportation, and disposal. MSWM system in India is still not following its entire chain with full strength. According to the database of Swachh Bharath Mission (SBM) and State-wise status of implementation of various components under SBM (up to September 2016) of the MUD, only 21.45% of the MSW is treated, and the remaining is still going to the landfill (SBM, 2016). The existing status of MSWM in India is depicted in Fig. 1. According to Solid Waste Rule 2016, waste should be segregated by the generator and stored them in three separate streams namely domestic hazardous, bio-degradable, and non-biodegradable