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Utilization of Municipal Solid Waste for Biogas Production in India: A Review

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ABSTRACT
Rapid population growth and urbanization have leads to generation of solid waste, its improper management causes hazards to inhabitants which affect environmental sustainability, the management of municipal solid waste requires proper maintenance and infrastructure, otherwise contaminate the environment. This waste can be use for meet the energy crisis in the urban region and produce the organic manure based on the physical and chemical characteristics. Anaerobic digestion is a suitable technique for waste-to-energy a useful process through pyrolysis, which provides biogas that can be use as directly for cooking in households. The present study focused that characteristic of municipal solid waste and energy generation from organic solid waste generated from the households and provides the comprehensive review of municipal solid waste management in India. It will helpful to tackling the waste management and energy crisis.

Key words: Population growth, Urbanization, Municipal Solid waste, anaerobic digestion, Biogas, Organic manure.

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I. INTRODUCTION

The increase in population and urbanization accounts increasing the generation of solid waste and leads to hazard problems due to improper management in urban region and also affects the potential economic value (Beede & Bloom 1995; Marques and Simoes 2009; Simoes and Marques 2011, 2012; Batinić et al. 2011); Kannangara et al. 2018)). affect the culture and local climate (Hoornweg and Bhada-Tata 2012). Solid waste management is a greatest challenge for the government (Zurbrugg 2003; Ogwueleka 2009), Lifestyle and social status of people has been increased the solid waste in the cities (Sharholy et al., 2007). In developing nations there are several municipalities are struggle to manage rising trash loads, which leaves uncollected waste on the streets and in other public areas. They dumping of waste on any open plot, public space, and river or burn it in their backyard, thereby polluting the air. (Ogwueleka, 2003). Land filling or open dumping is the most conventional and well-liked method of disposing of municipal solid waste in worldwide. Municipal Solid Waste (Management and Handling) Rules, 2000 endorses the liability of the municipal authorities to construct suitable solid waste management methods and provide appropriate sites for disposal and sustainable treatment of waste in various regions in India. The sustainable solid waste management is very difficult to municipal authorities due to lack of infrastructure, suitable strategies and financial resources in various cities (Diaz et al., 1996). Consequently 90% of solid waste was directly disposed off on land in disorganized manner, (Das et al., 1998). The environmental impacts due to improper and illegal dumping of municipal solid waste or its mismanagement could leads to various harmful effects, that are spreading of vector diseases, foul odor from organics waste materials, air pollution problems by open dumping, leaching of toxic compounds and change the ground and surface water quality, climate change, degradation of existing landscapes, and contamination of soil. (Renju et al., 2021). The open dumping of municipal solid waste is a common exercise in India (Satish et al., 2022). Furthermore, there are many studies demonstrated that the relationships between waste characteristics and demographic and socioeconomic conditions. Lakioti et al. (2017).

There is a physical and chemical method for treatment of wastes, which is bioconversion of wastes in two methods an anaerobic and aerobic processes, an anaerobic process has many advantages over aerobic digestion. Around the world, non-renewable energy sources account for around 75% of energy production, which is done by burning fossil fuels and emitting gases into the environment. (Korhonen et al., 2018). It's potential for making of energy using the biogas generation, hence, it is an attractive option (Mahes & Omalaka 2011), it can be replaced the fossil fuels and reduces the green house gases. The bio conversion technique is also applied for waste water and sewer. The fuel production from solid waste is a new interest (Garg et al., 2009; Séverin et al., 2010), in some countries there are various environmental problems and limited land availability is affecting the production of gas and leachates, hence, it needs to improve the technology (Abu & Abu 2000). The management of solid waste in an engineered landfill bioreactor is found to be the better option for treatment. An anaerobic treatment will decrease the long-term environmental risks and provides a valuable energy source in generation of methane with different types of waste suitably selected from the composition. In this regard organic waste, sewer and waste water with food waste are found to be productive more biogas. (Mahes & Omalaka 2011). Food waste or organic waste is the major factor for the small scale and produce the biogas (Dennison et al., 1996; Bandara et al., 2007; Kamran et al., 2015; Ozcan et al., 2016). The policies, which are related to the municipal solid waste are different (Dora et al., 2020), waste management encompass with various activities involved from collection to dumping and few eco-friendly practices for waste management are segregation, recycling, treatment and composting as well as the 4Rs principle is an efficient way namely reuse, refuse, reduce, and recycle of solid waste to decrease the waste generation with help of technologies. The methane production capability's accuracy might be further improved if specifications for locally generated wastes could be established. (Mahes & Omalaka 2011).

Working toward a solid waste management system that is environmentally, economically, and socially sustainable is urgently necessary. It will be possible to handle this enormous amount of waste sustainably and effectively by using the waste to energy generation option. (Singha et al., 2011). Therefore, it is an important to understand that now biogas as a source of energy, whereas some studies focusing on barriers to renewable energy as a whole (Ashraf et al., 2009). The best models for forecasting the potential for methane generation are found after a review of the literature. Anaerobic digestion is used to predict methane from sewage and waste water. The chemical composition of municipal solid waste is the key determinant of methane production, sewage, and waste water. The basic parameters of BOD and COD concentration are provided by the data acquired by Alam et al., 2010; Surendra et al., 2011; Fenton and Kanda 2017), and on biogas in specific regions to recover the energy sources (Katuwal and Bohara 2009; Poeschl et al., 2010; Chen et al., 2014; Surendra et al., 2014; Shen et al., 2015; Khan and Martin 2016). One of the major resources for biogas production is agricultural sector (Jørgensen, (2009). Animal husbandry in rural areas (Tatiana and Vladimir 2019).

II. Methodology

The methodology for the biogas production from municipal solid waste from selected organic waste materials through anaerobic process, in order to decrease the treatment time of waste with digestion technique and solution for increase biogas production along with several tactics identified in the literature, the bio gas production depends on the nature of the solid materials and include temperature, C/N ratio, organic loading rate, pH, Microbes balance, partial pressure, hydraulic retention time etc., (Tchobanoglous et al., 1993; Angelidaki and Ahring 1994).

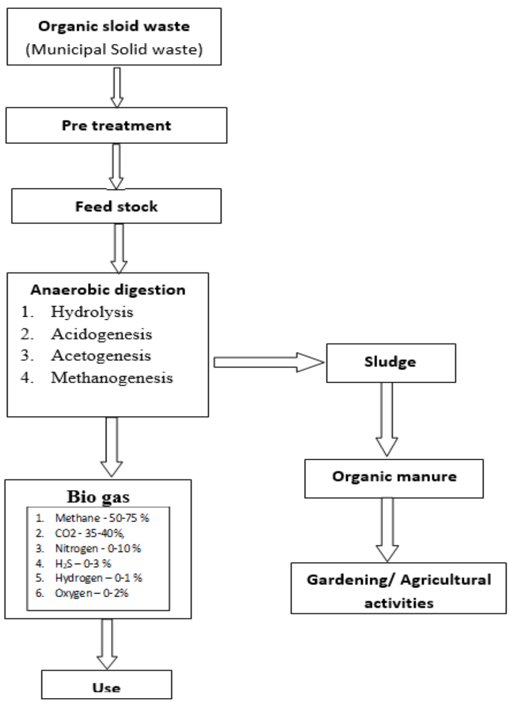
2.1 Characteristics and Composition of solid waste

Approximately 3 billion tonnes of municipal solid waste produced annually in the world, with 32–56% Fisgativa and Tremier 2015) of MSW being organic biodegradable waste. (Kamran et al., 2015; Ozcan et al., 2016), households and restaurants are the major sources for food wastes (Braguglia et al., 2017). Organic waste like vegetables, Fruits are from market (Satish et al., 2022), furthermore, the composition of food waste varies depending on the region and the cultural habits, etc., (Ruth 1998; Parthiba et al., 2018). Generally, taking into consideration that moisture plus total solids, wet weight, volatile solids (Zhang et al., 2014), and also composed mostly of easily degradable carbohydrates, proteins and lipids and has a low C/N ratio (Uçkun Kiran et al., 2014). It is also rich in macro-elements but lacks trace elements (Zhang et al., 2011; Banks et al., 2012; Pham et al., 2015). Moreover, is generally acid or sub-acid substrate being suitable for biodegradation (Fisgativa and Tremier 2015).

2.2 Methods

Anaerobic digestion is a technic with wide application in the degradation the materials are oxidized and converted into biogas and spent slurry containing the remaining amalgams with microbial metabolism (Ziganshin et al. 2010). UASB (up-flow anaerobic sludge blanket) reactor, Natural zeolites methods has been used to produce for bio gas from food waste (Loizia et al., 2019). Thermal pre-treatment, anaerobic digestion and hydrothermal treatment method was applied to produce biogas and hydro char from Yard wastes (Panigrahi et al., 2020; Sharma et al., 2020). anaerobic digestion in waste water treatment process is used to produce the Energy using combined heat and power from Sewage sludge (Kiselev et al., 2019), Biogas and liquid biofertilizer are produced by Hydromechanical pretreated Municipal food wastes and anaerobic degradation from Municipal food wastes (MFW) (Paul et al., 2017). Municipal wastes Recycled materials are used for production of Biogas with landfill cover Separate collection system, anaerobic degradation and land fill processes (Ribic et al., 2016), Organic solid wastes are used for production of Biogas, hydrogen energy, lactic acid Nutrient recovery through Co-digestions and multiple product recovery processes (Wainaina et al., 2020).

Figure 1: Flow diagram of Biogas Production Process



III. Results and discussions

According to Hoornweg and Bhada-Tata (2012), waste composition is affected by culture, economic development, local climate and energy sources. At the small scale, food waste or organic waste is the main component with varied ratio of the waste stream in previous studies (Dennison et al., 1996); Bandara et al., 2007; Kamran et al., 2015; Ozcan et al., 2016). The municipal solid waste is collected from the streets and segregated the organic waste from the composition, there are different characteristics of the waste in the composition that are Paper - 38.85 %, Textile -2.52 %, Wood, trees etc., 1.46 %, Food waste -38.33 %, Plastics - 15.61%, Leather, rubber -0.20 %, Other metal (including debris below 5 mm) -0.49 %, Ferrous-metal - 0.28 %, Non-ferrous metal -0.22 %, Glass - 1.26 %, Other non-combustible material (Ceramics, sand) - 0.78 %, etc., indicated in table 1 & figure.3 (Houng et al., 2013; Kieu et al., 2020).

Municipal solid waste has various chemical parameters which indicates the suitability of biogas or gaseous composition such as moisture-53.96 %, Ash content- 4.96 %, Carbon-22.36 %, Hydrogen-3.46 %, Oxygen-14.62 %, Nitrogen-0.38 %, Sulfur-0.15 %, Chloride-0.11 % (indicated in table 2 & Figure 3), and energy content is from dry waste has 5,322.44 kcal/kg, wet waste has high value is about 2,451.31 kcal/kg, and the wet waste has low value is about 1,940.74 kcal/kg. Comparatively less energy from wet waste low value with dry and wet waste high values (indicated in Table 3 & figure 4). The dry waste has more energy content it can be used as biomass energy, the wet waste either low value or high value both are suitable for production of biogas. In the process of biogas there are some physical parameters affecting the microorganism growth like pH and temperature in the reactor. Generally, the growths of methanogenic microorganisms are active at the pH range from 6.5 to 7.2 (Boe 2006), the temperature is also an important factor for the growth and metabolism of bacteria (Song et al., 2004; Parashar et al., 2019). Some of the microorganisms (e.g. acetotrophic methanogens) are very sensitive to the temperature changes, but the high temperature favors high solubility of the organic compounds, chemical, biological reaction, and degradation of larger molecules into smaller ones (Parashar et al., 2018; Parashar et al., 2019). Adani et al. (2002) observed that changes of temperature have possible during biological process to achieve bio stabilization of the waste. (Tambone et al. 2011). The production of biogas from the organic solid materials through anaerobic degradation in the digester, should monitor the physicochemical parameter and climatic condition to create the favorable conditions to the microorganisms for easy degradation of the waste composition, moisture content, partial pressure, C/N ratio, organic loading rate for existing the microorganisms or Microbes balance, etc., (Pham et al., 2015). Dehkordi et al., 2019; Panigrahi and Dubey 2019).

3.1 Microorganisms

The microorganisms activities are important to degrade the organic waste materials from the municipal solid waste compositions, various microorganism are identified by the researches such as Hydrolytic bacteria such as Bacteroides, Lactobacillus, Propionibacterium, Sphingomonas, Sporobacterium, Megasphaera, Bifidobacterium are degraded the Simple sugars, peptides, fatty acids through fermentation process, in Acidogenesis method the Syntropic bacteria like Ruminococcus, Paenibacillus, Clostridium are very active to degrade the Volatile fatty acids in Acetogenesis process. The Acetogenic bacteria like Desulfovibrio, Aminobacterium, Acidaminococcus are very active to degrade the Acetic acid (CH_3COOH), (Zieminski and Frąc 2012; Lauwers et al., 2013).

Anaerobic digestion has three phases that are enzymatic hydrolysis, acid formation, and gas production; Figure 1 flow diagram depicts the digestion process. (Anukam et al., 2019

3.2 Pretreatment

The pretreatment process will increase the efficiency of the reactor for biogas production, in this treatment removal of Impurities, breakdown of larger molecules into smaller, the process was carried out by various procedures for instance mechanical, thermal, chemical, acid and alkaline hydrolysis, and bacterial enzyme hydrolysis etc., (Barlindhaug and odegaard 1996).

3.3 Feedstock

Feedstocks is the process for Anaerobic Digestion, it is a collection of the cattle dung or manure, food waste and sewage sludge, these are easily biodegradable materials and an important factor in anaerobic degradation (Jerger and Tsao 2006). The micro organisms can break down the biomass and increasing the efficiency of the digester using biomass as feed stock in digester (Richards et al., 1991a; Richards et al., 1991b), There are various methods are using in worldwide for the preprocessing of the contaminated feedstock materials. (Sunil Kumar 2020).

3.4 Enzymatic Hydrolysis

In initial stage, facultative or obligate anaerobic hydrolytic bacteria release hydrolases that break down big polymer molecules. The polymers are converted into oligomer or monomeric molecules in hydrolysis. Oligosaccharides and monosaccharides are formed from polysaccharides; for instance, illustrates the creation of glucose molecules by starch hydrolysis. lipids are transformed into glycerol and fatty acids; proteins are broken down into peptides and amino acid. The hydrolysis rate is comparatively slower than the rate of acid formation, it depends on the characteristic of substrate, temperature pH and bacterial load and activity, and also enzyme production, adsorption of enzymes affect the hydrolysis rate. Bryant (Bryant 1979) find out that Enterobacter and Streptococcus are genera of anaerobes that are responsible for hydrolysis.

3.5 Acidogenesis

Acidogenesis occurs when hydrolysis products are fermented along with carbon dioxide, hydrogen, and ammonia to volatile fatty acids such as acetic acid, propionic acid, butyric acid, and isobutyric acid. During acidification, facultative anaerobic bacteria use oxygen and carbon to create anaerobic conditions for methanogenesis.

3.6 Acetogenesis

Acetogenic bacteria belongs to genera Syntrophobacter and Syntrophomonas (Schink 1997). The acid phase converted into acetates (2) and hydrogen. Acetates will be used by methanogens in the next stage. However, hydrogen will release and effects to microorganisms. Therefore, in anaerobic digesters, acetogenic bacteria will be stayed in syntrophic courting with hydrogenotrophic methanogens that eliminate the hydrogen through making use of it for methane formation. Also, acetogenesis is the phage, which depicts the performance of the biogas production due to the fact 70% of methane arises while acetate reduces.

3.7 Methanogenesis.

In the last stage methanogenesis is carried out by methanogens belonging to archaea. Methane is produced by fermentation of acetic acid or reduction of carbon dioxide. Therefore, the products of the previous stage, i.e. acetic acid, hydrogen and carbon dioxide, serve as precursors for methane formation; methanogenesis allows higher system stability and efficiency by simultaneously providing nutrient balance and a strong buffering capacity (Li et al., 2010; Kwietniewska and Tys 2014). Only 30% of the methane produced in this process and reduction of carbon dioxide by methanogens. (Griffin et al., 1998; Karakashev et al., 2005).

These processes started by hydrolyzing for breakdown of large molecules into smaller units, the amino acids and sugars are converted into various byproducts like NH_3, H_2, CO_2, and other organic acids by acidogenic bacteria. Other organic acids produced in the above process are converted to acetic acid by acetogenic bacteria along with NH_3, CO_2 and H_2. In the last step, the methanogenic microorganism has transformed these digested materials into CH_4 and CO_2 (Appels et al., 2008). Among all the above microorganisms, only the methanogenic microorganisms are anaerobic and available naturally in the marshes, rumen of the cows and the brackish water (Holand et al., 1987). The most identified genera of the methanogenic microorganisms are Methanococcus, Methano bacterium, Methanosarcina, Methanospirillium, and Methanobacillus. Most of the methanogenic microorganisms are preferably the rod, cocci or sarcinate in the shape and always Gram-positive and not motile (Holand et al., 1987). The majority of the methanogenic microorganisms are pleomorphic, cemoliho heterotrophic and their length varies between 2 and 15 µm (Holand et al., 1987). Methanogenic microorganisms are morphologically diverse but physiologically quite similar. The digester requires anaerobic conditions for effective functioning and growth of the anaerobic microorganisms (Appels 2008). The hydrolysis is mainly the rate-determining step in the anaerobic digestion (Reynolds and Richards 1995; Ghyoot and Verstraete 1997; IWA 2002).

The biogas is colorless, relatively odorless and flammable gas that burns with a blue fame, and possesses a high calorific value (4500–5000 kcal/m3) (Madu and Sodeinde 2001). It is a mixture of CH_4 (50–75%), CO_2 (25–45%), N_2 (2–8%), H_2 (0–1%), O_2 (0–2%), H_2S (0–4%) and a small proportion of water vapors (0.5 –1.5 %), (Song et al., 2004; Sunil Kumar 2020) indicated in table 4. Odor will release in degradable of waste that under optimal conditions, i.e. moisture, pH, nutrients, and anoxic or partially anoxic environment, can ferment to produce odors (D'Imporzano et al., 2008; Scaglia et al., 2011). The efficiency of anaerobic digestion can be increased by removing CO_2 and CO from the biogas composition.

IV. Conclusions

The safe disposal of organic solid waste is very important to the municipalities, based on the physical and chemical characteristics of the solid waste the biogas can produce through various processes. The microbial existence and diversity are very important to decomposition of organic solid materials, which reduce the pollution and contamination of surface water and pathological developments. The reviews suggested that solid waste management and biogas production influences the economic and sustainable sources of energy, if can be replace an existing source of energy (nonrenewable) in significant proportions, the wet waste has sound calorific value for easy production of the biogas. Finally, the waste to energy process should expand to all the regions to meet the sustainable development and energy problems with best practices.

Figure 2. Composition of municipal solid waste in percentage

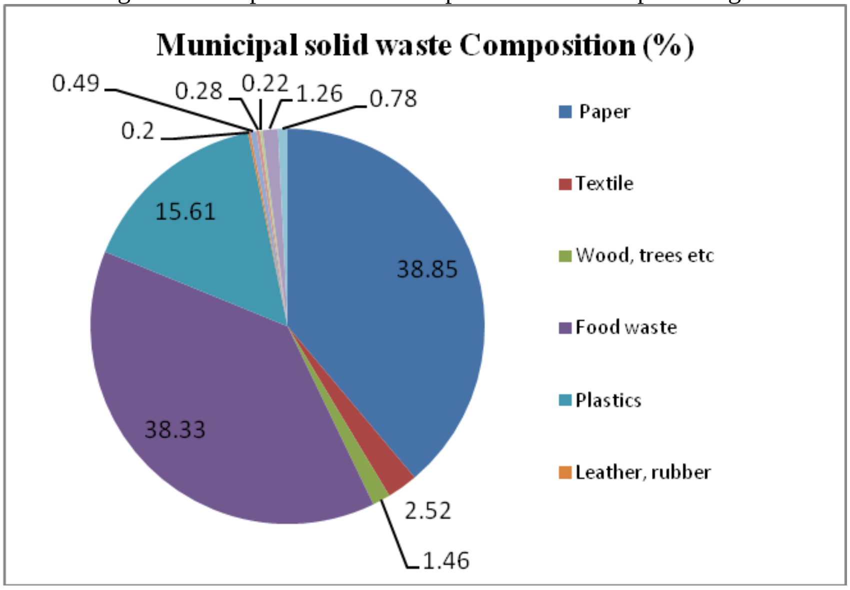


Table :1. Typical physical composition of MSW in the study area

S.No	Solid material characteristic	Composition percentage (%)
1	Paper	38.85
2	Textile	2.52
3	Wood, trees etc	1.46
4	Food waste	38.33
5	Plastics	15.61
6	Leather, rubber	0.20
7	Other metal (including debris below 5 mm)	0.49
8	Ferrous-metal	0.28
9	Non-ferrous metal	0.22
10	Glass	1.26
11	Other non-combustible material (Ceramics, sand)	0.78
	total	100

Table: 2. Typical chemical composition and energy content of MSW

S.No	Chemical composition	Percentage (%)
1	Moisture	53.96
2	Ash content	4.96
3	Carbon	22.36
4	Hydrogen	3.46
5	Oxygen	14.62
6	Nitrogen	0.38
7	Sulfur	0.15
8	Chloride	0.11
	Total	100 %

Figure 3. Chemical composition in municipal solid waste

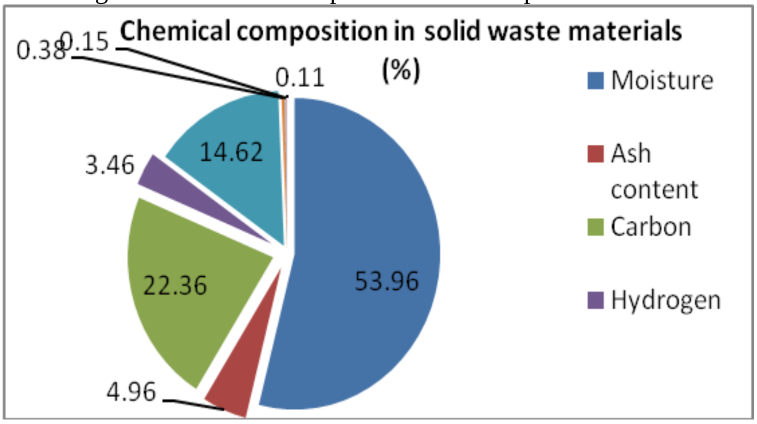


Table: 3. Energy content in the solid waste

S.No	Energy content	kcal/kg
1	Dry	5,322.44
2	Wet - high value	2,451.31
3	Wet - low value	1,940.74

Figure 4. Energy content in the municipal solid waste

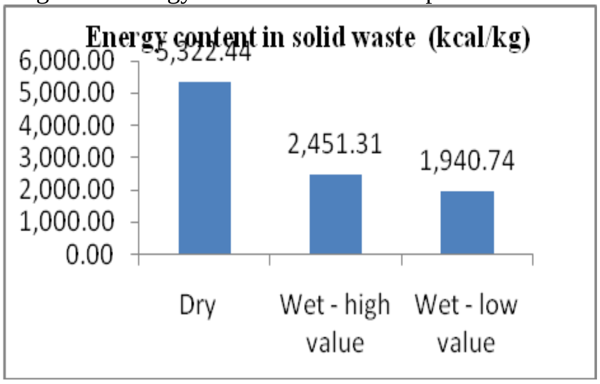


Table: 4. Composition of biogas

S.No	Biogas Constituent	Percentage
1	Methane	50-75 %
2	Nitrogen	2-8 %
3	Carbon dioxide	25-45 %
4	H_2S	0–4%
5	Oxygen	0-2%
6	hydrogen	0-1 %
7	Water Vapors	0.5 – 1.5

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