International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 6 (2019) pp. 1265-1268

Assessment of Bio-Gas from Municipal Solid Waste for Generation of Electricity– A case study of Agartala city

Sukanta Chakraborty[1], Dr. Kaberi Majumdar[2], Dr. Manish Pal[3], & Dr. Pankaj Kumar Roy[4]

[1]Junior Engineer, Public Works Department, Govt. of Tripura, Tripura- 799005, India.

[2]Assistant Professor, Electrical Engineering Department, Tripura Institute of Technology Narsingarh, Tripur- 799009, India.

[3]Associate Professor, Civil Engineering Department, National Institute of Technology Agartala, Tripura- 799055, India.

[4]Professor, School of Water Resources Engineering, Jadavpur University, Kolkata- 700032, West Bengal, India.

Corresponding author

Abstract

Municipal solid waste (MSW) management seems to become one of the major concerns of the modern city planning. The increasing quantum of MSW has pressed hard on policymakers to introduce sustainable modes of waste management techniques considering the aspect of 4 R Principle. At the same instant the energy demand of modern city life has also appeared to be a matter of study with the changing environmental and socio-economic scenarios. On the verge of these dual challenges selection of proper technology for sustainable waste management with sufficient scope of energy recovery is the call of the period. Considering the aforementioned fact an attempt is made in this paper to evaluate the potential of MSW generated in Agartala city for generating bio-gas on preliminary basis for electricity generation. The study shows that with the present trend of waste quantity and quality approximately 249.41 MT of MSW will be produced per day by 2021 empirically yielding 52376.10 m^3 of methane and this may further increase to a value of 108559.50 m^3 by the year 2051 when the approximate generation of MSW may reach 516.95 MT per day for the city of Agartala.

Keywords: MSW, Energy recovery, Waste characterization, Biogas, Electricity.

INTRODUCTION

Municipal solid waste generally refers to the waste generated from the residential, commercial and other complexes. Generally the municipalities and urban local bodies are responsible for the collection and management of such category of waste. The rapid development of urban life and gradual change in the lifestyle of a considerable portion of habitants of urban areas, the burden of solid waste management on urban local bodies is increasing in an alarming rate [1, 2]. Particularly this trend in much predominant in developing countries like India.

At the same time with the growth in industrial as well as commercial activities in parallel with the urban lifestyle, the demand of energies of numerous forms are also pressing hard in their respective sources. As such till date non-renewable energy sources are the prime contributors of energy demand throughout the Globe. But the continuous depletion of conventional energy resources is sticking the concern into the search for new energy sources to be used. The potential energy sources have been emerged as renewable energy resources. For last several decades investigations on research level as well as pilot project level are made on multifarious sources of renewable energy. To counteract with the growing demand exploration of sustainable sources energy is the call of the hour.

In the traditional sense, renewable sources of energy are those that can be replenished by nature, such as hydropower, wind power, solar power and biomass. Municipal Solid Waste (MSW) in general contains a significant fraction of paper, food waste, wood and yard trimmings, cotton, leather etc and can be considered as a source of biomass. Materials derived from fossil fuels, such as plastics, rubber, and fabrics, are also found in MSW. The U.S. Environmental Protection Agency has also considers MSW as a renewable energy resource [3].

The declining level of fossil fuel in its underground reserve triggers the production of biogas from municipal waste at different countries. This approach is not only meeting the remarkable portion of energy demand but also helping to maintain clean environment by reducing the pressure on landfills. Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic conditions. Small internal combustion engines with generator can be used to produce electricity with clustered dwellings. Bio-digesters can be used to treat municipal waste and generate electricity. One of the options to utilize biogas is to produce electricity using a gas engine or gas turbine. [4, 5]

At the same instant it is also a matter of concern that chemical composition of the MSW mass is the most important factor for ascertaining the potential capacity of a particular waste stream to be used in biogas generation. The higher fraction of

biodegradable materials makes it more convenient to utilize the waste for biogas production. The present paper is an approach to determine the potentiality of municipal solid waste of Agartala city to be utilized in the production of biogas as a part of waste to energy approach.

STUDY AREA

The present study is made to ascertain the potentiality of the MSW of Agartala city for biogas generation. The study is made by collecting waste quality data based on the characterization result of solid waste of the city. The study area for the work presented in this paper is mainly concentrated on the city of Agartala, which is under the jurisdiction of Agartala Municipal Corporation. The total area of the city is approximately 76.504 sq Km. Entire central zone and lion share of areas of Northern and southern zone of the city is a flat terrain. Average altitude of the city is 12.80 mtr. The central zone of the city has lower altitude and few areas are below the bed levels of Howrah River and Canal Katakhal flowing from East to West in the South and North sides of the zone.

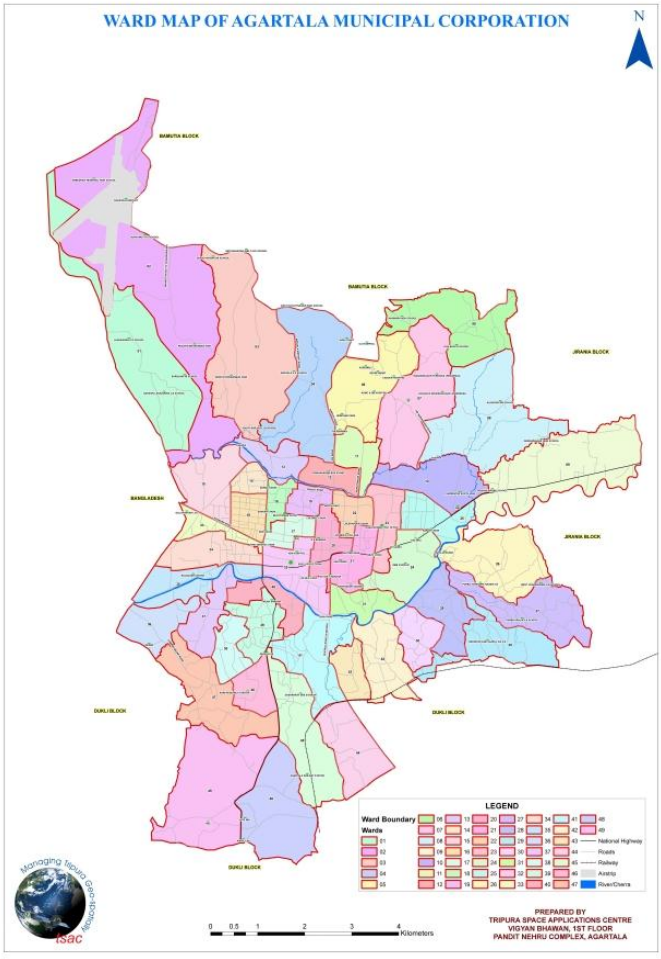

Fig. 1: Map of Agartala Municipal Corporation (Source: AMC)

ANALYSIS & DISCUSSION:

MSW is a heterogeneous material and its physical composition is dependent on socio-economic level and climatic conditions [6]. Systematic MSW sorting and recycling is not implemented in Agartala city, although materials with resale values, such as metals, paper, and plastics, are highly recycled by the informal recycling sector. MSW incineration in developing countries is generally limited by several factors, including significant capital and operating costs, potential environmental impacts, and technical difficulties of operating and maintaining an incinerator and its pollution control equipment. Moreover the moisture content in MSW in developing countries is generally in higher side resulting in the lowering of the MSW's energy content.

Accurate prediction of municipal solid waste's quality and quantity is crucial for designing and programming municipal solid waste management system of a city. But predicting the amount of generated waste is difficult task because various parameters affect it and it's fluctuation is high. However, primarily the solid waste generation of a city is the function of it's population and estimation of population to predict solid waste generation of the city is imperative. The predicted amount of MSW based on the population data obtained through statistical techniques is illustrated in Table 1 for the Agartala city assuming constant waste generation rate of 0.50 kg/capita/ day.

Table 1: MSW generation in Agartala City

Year	Population	Rate of waste generation	Predicted quantity of MSW per day
2011	3,99,688	0.50 kg/capita/day	199.84 MT
2021	4,98,818	0.50 kg/capita/day	249.41 MT
2031	6,37,566	0.50 kg/capita/day	318.78 MT
2041	8,15,928	0.50 kg/capita/day	407.96 MT
2051	10,33,906	0.50 kg/capita/day	516.95 MT

Organic portion or biodegradable materials of municipal waste such as food waste, vegetable waste, animal material, kitchen waste etc. can be converted into a gaseous fuel called biogas by the anaerobic digestion or fermentation in a digester in presence of methanogenic bacteria. Biogas is mainly composed of 50 to 70% methane (CH_4) 30 to 40% carbon dioxide (CO_2) and low amount of other gases.

The climatic as well as the socio-economic structure of the state of Tripura is much closer to the ideal condition of biogas production. The ideal temperature for biogas production is 30^0 to 45^0 C. Tripura has mostly warm temperatures throughout the year due to the prevailing tropical/subtropical climate. More over raw material for biogas digester in the form of municipal organic waste and water are readily available. The characterization data of MSW of Agartala city is presented in Table 2 & 3 below:

Table 2: Physical Composition of Municipal Solid Waste in Agartala city

Sl No	Component	Average percentage
1	Glass & Metals	1.40%
2	Food Waste	55.46%
3	Combustible matters	17.25%
4	Plastics	7.15%
5	Recyclable matters	2.00%
6	Inert materials	15.37%
8	Density	454.01 kg/cum

Table 3: Chemical Composition of Municipal Solid Waste in Agartala city

Sl No	Component	Average percentage
1	Moisture Content	36.40%
2	Density	453.01 kg/cum
3	Organic Carbon	37.50%
4	Total Nitrogen	0.89%
5	Potassium as K_2O	0.40%
6	Phosphorus as P_2O_5	0.48%
7	C/N Ratio	42.36

Physical composition analysis of the MSW of Agartala city shows that there is a mixture of different types of components with a significant portion of them being compostable. This high amount of organic content indicates that the waste is very suitable for anaerobic digestion.

Following chemical equation can be used to estimate theoretical yield of biogas from organic waste. Computation of volume of gases on the basis of the equation shows that about 0.21m^3 methane may be available per Kg of organic waste [7].

$$C_aH_bO_cN_d + (4a-b-2c+3d)/4\ H_2O \text{ -------> } (4a+b-2c-3d)/8\ CH_4 + (4a-b-2c+3d)/8\ CO_2 + d\ NH_3$$

The predicted methane production potential of MSW of Agartala city is presented in Table 4 below, based on the thumb rule stated above:

Table 4: Methane generation potential of MSW of Agartala City

Year	Predicted quantity of MSW per day	Predicted volume of Methane gas
2011	199.84 MT	41966.40 m^3
2021	249.41 MT	52376.10 m^3
2031	318.78 MT	66943.80 m^3
2041	407.96 MT	85671.60 m^3
2051	516.95 MT	108559.50 m^3

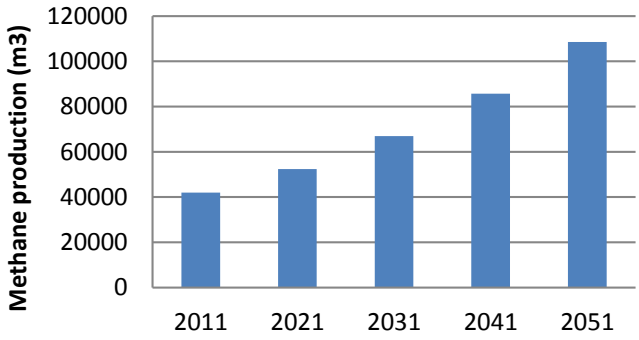

Fig 2: Methane generation from MSW in Agartala city

CONCLUSION

Bio gas seems to become one of the emerging sources of energy in recent years because of having its dual benefit – Solid waste management and Electricity generation. The present approach of study shows that the MSW of Agartala city has a good potential to be treated through anaerobic digestion for producing bio-gas as a route for energy recovery from the waste. It will surely help in minimizing the pressure on the sanitary landfill sites as till day, land filling is the only method of MSW disposal practiced in the state. Moreover this approach will generate wealth through electricity production from biogas. The laboratory based characterization data of the representative samples of MSW collected from Agartala city shows that a good quantity of biogas can be recovered from the waste based on the empirical estimation procedure. It is predicted that volume of methane are 52376.10 m^3, 66943.80 m^3, 85671.60 m^3, 108559.50 m^3 in the year 2021, 2031, 2041 and 2051 respectively and these volumes are adequate to generate electricity.

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BIOGRAPHY

Sukanta Chakraborty obtained his M.Tech in Environmental Engineering from NIT Agartala, India. His research interest deals with Solid Waste Management, Environmental Planning and EIA. Presently he is working as Junior Engineer, Public Works Department, Govt. of Tripura.

Kaberi Majumder obtained her PhD in the field of Renewable Energy from Jadavpur University, West Bengal & M.Tech in Electrical Engineering from Tripura University. Currently she is an Assistant Professor of Electrical Engineering Department at Tripura Institute of Technology, Narsingarh, Tripura, India.

Manish Pal obtained his PhD in the field of Water Transportation and Management from Jadavpur University, West Bengal & Masters of Engineering from BESU, Shibpur in the field of Transportation Engineering. He is an Associate Professor in Civil Engineering Department at National Institute of Technology, Agartala, India.

Pankaj Kumar Roy obtained his PhD and M.Tech in Water Resources Engineering from Jadavpur University, West Bengal, India. Presently he is a Professor in School of Water Resources Engineering, Jadavpur University.