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MSW A Potential Energy Resources: A Two Stage Anaerobic Digestion

Archana Paranjpe, Abhay Kumar Sharma, R.K.Ranjan, V.K.Bajpai, Vishal Paranjape V

Abstract— ***Present investigation reveals the biodegradability of municipal solid wastes (MSW) in context of Jabalpur city [1] (at 23˚10΄North latitude and 79˚57΄ East longitude, at an altitude of 393 meters above mean sea level) and harnessing energy through two stage anaerobic digestion. A critical study of various process parameters affecting the anaerobic digestion has been analyzed. During the anaerobic digestion of MSW it has been seen that the retention time of the process increases as compared to other waste such as fruits and vegetable waste, cow dung, agricultural residues etc. With the use of suitable bio-methanization technology the twin objectives (a) waste reduction and (b) the environmental problems can be achieved. The present work will help all academicians, rural and urban energy industry people in generating eco-friendly energy and maintaining environment too. In this study the biodegradability of the MSW organic fraction has been tested and in particular a comparison between the production of biogas from landfills and organic wastes in anaerobic conditions has been performed. Two stage digestion of this kind of wastes were proved a better efficiency than single stage digestion.***

Key words: bio-methanization, MSW, biogas, two stage anaerobic digestion.

I. INTRODUCTION

There is explosion in the population consequently large amount of municipal solid waste generates in the urban area. The waste sector is facing various challenges such as quantum increase, complexity, risk of damage to human health, biodiversity, ecosystems, economic unattractiveness of the 3Rs (Reduce, Recycle, Reuse), the sector's contribution to climate change etc. [2] At present, a surprising 3.4-4 billion tonnes of municipal and industrial solid waste and up to 300 million tons of hazardous waste are annually produced worldwide, [3] out of that two billion tons of MSW. Over the next decade this number will grow much higher, increasing global demand for solutions that convert waste into heat and electricity. [4] Urban India generates 188,500 tonnes per day (68.8 million tonnes per year) of MSW at a per capita waste generation rate of 500 grams/person/day.

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***** Correspondence Author (s)
Archana Paranjpe, M.Tech. Scholar, Energy Technology, EE Deptt., Gyan Ganga Institute of Tech. and Sc., Jabalpur, India
Prof. Abhay Kumar Sharma, Professor, Dept. of Mechanical Engineering, Gyan Ganga Institute of Tech. and Sc., Jabalpur, India
Prof. R.K.Ranjan, Professor, Dept. of Mechanical Engineering, Gyan Ganga Institute of Tech. and Sc., Jabalpur, India
Prof. V.K.Bajpai, Professor, Dept. of Mechanical Engineering, Gyan Ganga Institute of Tech. and Sc., Jabalpur, India
Prof. Vishal Paranjape V, Professor, Dept. of Mechanical Engineering, NIT Kurukshetra (Institute of National Importance), India

The total waste generation figure is achieved by extrapolating the total tonnage of wastes documented for 366 cities (70% of India's urban population). MSW is one of the major environmental problems of the urban and sub-urban. Rapid industrialization and population explosion in India has led to the migration of people from villages to cities, which generate thousands of tons of Municipal Solid waste daily. The municipal solid waste amount is expected to increase significantly in the near future as the country strives to attain an industrialized nation status by the year 2020. [5]Solid waste management (SWM) has become a global issue and is of a major concern, especially in developing countries, due to various environmental problems, such as pollution of air, soil and water and generation of greenhouse gases from landfills. Landfill has great limitation due to its environmental impact and resource waste and result in being restricted in some counties. [6] Many studies have been conducted on the use of MSW for production of Biogas.

One of the studies suggests that by having decentralized anaerobic digesters in the localities, the odour problem caused by MSW from bins and during long transportation distances can be minimized. (7) Apart from this bring out the dual purpose of anaerobic digesters, not only will they provide a solution to the solid waste crisis, but also to the energy crisis.

In one-stage system, given the very large biodegradable organic content of FVW and food waste, a major limitation of anaerobic digestion of these wastes is a rapidly acidification decreasing the pH and a large volatile fatty acids production, which stressed and inhibited the activity of methanogenic bacteria. (8)Two stage concepts was first introduced by Pohland and Ghosh (1971) (9) and by Ghosh (1975). (10) This two-phase system was first used for soluble substrates and liquid waste, then phase separation has been studied by digestion of solid vegetable waste. (11) Three mainly advantages compare with single anaerobic digestion, including less detention time, higher gas conversion efficiency and higher methane concentration.

1.1 Status of Municipal Solid Waste Management in Selected Metro Cities, 2004-05
(Source: SOER, 2009, MOEF Note: kg/c/day: kilogram per capita per day)

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Particulars	Kolkata	Chennai	Delhi	Mumbai
Area (sq.km)	187.33	174	1484.46	437.71
Population (census 2001)	45,72,645	4343645	10303452	11978450
MSW Generation (tones/day)	2653	3036	5922	5320
MSW generation rate (Kg/day)	0.58	0.62	0.57	0.45

2.1 Composition of MSW in Jabalpur city (Braber, 1995; Speece, 1996;Mahmoud,2002).

S.NO.	Contents	%
1.	Paper and cardboard	5-15
2.	Plastic	2-8
3.	Inert Materials	5-15
4.	Compostable Materials	40-45
5.	Metals	1-2
6.	Moisture content	Rest

[12]Currently, biological treatment methods such as composting and Anaerobic Digestion (AD) offer the only route for recycling organic matter and nutrients from the organic fraction of municipal solid waste (OFMSW). Composting can diminish the organic matter by about 50% through the formation of carbon dioxide and water (Held *et al.*, 2002), but it represents and energy consuming process (around 30-35 kWh is consumed per tonne of waste input) while AD is a net energy producing process (100-150 kWh per tonne of input waste). AD is a process by which bacteria degrade organic matter and convert it to mainly carbon dioxide and methane. The main advantage of this technology is the destruction of organic components without the addition of oxygen and it produces useful by-products such as a gaseous fuel and stabilized solid residue that can be sold as a soil fertilizer. In contrast, aerobic treatment is plagued by the production of large amounts of activated sludge (about 10 times more than AD) and consumption of significant amounts of energy due to aeration

II. PROPOSED DUMPED SITE IN JABALPUR CITY

The Jabalpur is extending over an area of 122 sq.kms. The entire city is currently divided into 60 election wards and 8 Zones. The Jabalpur Municipal Corporation is responsible for collection, transportation, treatment and disposal of Municipal Solid Waste generated under MSW rule 2000. Hence, JMC has initiated development of MSW processing complex and sanitary landfill site at Kathonda, with an objective of waste reduction and ultimately effective management system. The existing SWM system for Jabalpur does not have an engineered landfill site for disposal of waste. The waste collected from secondary collection points is dumped in an unorganized manner at Ranital dumpsite in Jabalpur city area. The proposed SLF site is located at village Kathonda towards North West direction of Jabalpur city with a spread of over 24.60 hec with an investment of Rs. 750 lacks, the proposed Compost Plant will be designed to process 400 TPD (Tons per Day) of MSW with a progressive processing capacity of 800 TPD at the end of 20 years. The solid waste management facility shall involve composting of biodegradable and segregation of materials. Non biodegradable products such as stones, sand ceramics and metal components will be separated from biodegradable and other organic matter waste. But in present era the Kathonda site not used as a sanitary landfill site it is used only as a dumping purpose. Many types of toxic gases emitted to this site and to create the environmental problems. So this MSW reduces through the anaerobic digestion technology and generate the electricity.

III. MATERIALS AND METHODS

The basic experimental work for analyzing process parameters such as volatile solid (VS), total nitrogen (TN), total solid (TS), pH value, NPK, retention time (RT), gas yield etc. was setup in Gyan-Ganga Institute of Technology and science (GGITS) JBP, M.P. India.

A. Limitations of single stage AD

i] The pre-treatment involves removing of coarse particles and heavy contaminants. These pre-treatment steps cause a loss of 15 - 25 % VS, with corresponding decrease in biogas yield.

ii] The other technical problem is formation of a layer of heavier fractions at the bottom of the reactor and floating scum at the top. The bottom layer can damage the propellers while the top layer effected to mixing. This requires periodic removal of the floating scum and of the heavy fractions, thus causes lower biogas yield.

iii] The obtained digested sludge used as a fertilizer not totally moisture free, so large energy consumed for drying of this sludge before using.

iv] High consumption of water.

v] Higher energy consumption for heating large value.

B. Advantages of two stage anaerobic digestion

i. The digested loading with slurry form so not losses of Volatile solid.

ii. The scum floating layer not forms in the upper side of the digester due to recirculation of liquid.

iii. The obtained digested sludge totally moisture free and direct use for soil conditioner.

iv. The waste water after digestion used for the agriculture growth.

v. Design flexibility.

vi. More reliable for cellulose-poor kitchen waste.

vii. Only reliable design (with biomass retention) for C/N < 20.

viii. Less heavy metal in compost (when solids not methanogenized).

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C. Two-phase Anaerobic Process

The schematic diagram of the overall process is shown in photograph 2 the acidogenic reactor had total Volume of 15 liters batch type. When the hydraulic Retention time (HRT) of the acidogenic reactor was 4-5 days, and solid retention time (SRT) was 20-25 Days, the organic loading rate (OLR) from 1.0 to 6.0 kg With Cow manure and poultry waste (4:1:1) seeding with 1 liter fresh digested sludge of MSW and Cow manure. The acidogenic reactor, an anaerobic batch type combining a 3 layer of mesh wire filter, pH value of acidogenic reactor was 5-6 and methanogenic rector was 7.5-8.0.At temperatures of the acidogenic and methanogenic reactor were maintained at 35ºC -45ºC. In order to investigate the effects of co-substrate and stage of digestion on biogas production and the performance of t he system was investigated.

IV. ZONE WISE WASTE GENERATION

The Jabalpur City population as per the census data 2011 showing is over 24 lacks. It is spread over an area of 122 sq.kms. The entire city is currently divided into 60 election wards and 8 Zones. The Jabalpur Municipal Corporation is responsible for collection, transportation, treatment and disposal of Municipal Solid Waste generated under MSW rule 2000.

The Chemical / Physical Parameters of Organic Waste from Laboratory Test of MPPCB, Vijay Nagar, Jabalpur (30/11/2011).

(Source: Standard Zucconin, F. and deBertolidi, M., 1987)

S. NO.	Parameters	Acceptable value for the anaerobic digestion (%)	Actual value from the laboratory (MPPC) (%)
1	Organic Matter	40 -48%	42%
2.	Moisture Content	20-58%	38%
3.	pH value	6.6-8.5	6.79
4.	C/N Ratio	25:1-50:1	33:1
5.	Temperature	25-55ºC	40-45ºC
6.	Phosphorus	0.001-0.05	0.002
7.	Sodium	3.5-5.0	4.8
8.	Potassium	0.30-.45	0.35
9.	Nitrogen	>0.06	0.05

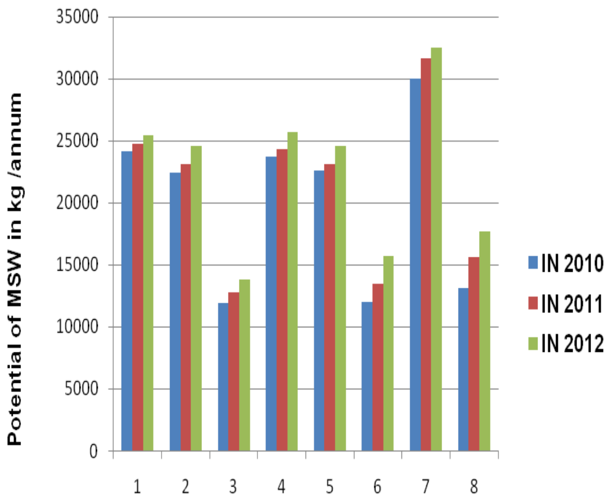


Fig. 1 Yearly Zonal MSW Distribution Source Municipal Corporation of Jabalpur city, MP & Prakash Chandra Agrawal, 2012)

Analytical Methods

The kinds of substrates (organic matters of MSW, Cow manure, poultry waste) for anaerobic digestion. pH value measures of acidified effluent, and final effluent) were taken from the pilot plant. Gas production and the composition of gas were monitored daily. Gas composition was determined with an infra-red gas analyzer (GA 94A) and gas detector (GASTEC, Japan); concentrations of CH_4, CO_2, and H_2S were monitored.

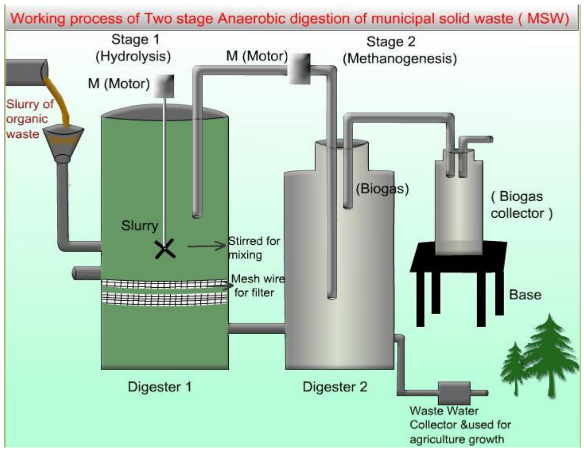
Experiments were carried out in two 15 liters cylindrical anaerobic digester and 1 liter High-density glass type tightly container. The substrate filled 80% of the container 20% left for gas collection, from 20% active inoculums (refer materials in methodology section) was used for all reactors for the total feedstock input.

C: N: P ratio

(14)Fermentable carbohydrate, nitrogen, phosphorous and other nutrients such as sodium, potassium, calcium, magnesium, iron and sulphur are needed for normal growth of bacteria involved in anaerobic wastewater treatment. Therefore, it is important to ensure that during the anaerobic treatment nutrients required for biomass to grow are sufficient. (15)For biological treatment to be successful, the inorganic nutrient necessary for the growth of microorganisms should be supplied in sufficient amounts; if the ideal concentration of nutrient is not supplied, there should be some form of compensation, either by applying smaller nutrient loads to the treatment system, or by allowing a reduced efficiency of the system.

Design and development of digester

i. Digester : Two batch type airtight digester (Capacity - 15 liters)
ii. Motor : Power - 5 watts (A.C. / 166-220 v/50Hz/0.8 m/400 l/h)
iii. Mesh wire filter : 3 layers - 5mm, 2mm, and 1mm diameter.
iv. Biogas container : glass type, capacity - 1 liter
v. Plastic tubes : 0.5 inch, 0 .25 inches.
vi. Burner : Bunsen type
vii Impeller : Iron rod manually rotates.



Photograph-1 Model of two stage anaerobic digestion system

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Photograph -2 Working setup of two stage anaerobic digestion system

Fig.2 revels the variation of pH value with respect to retention time. Initial the pH value is between 5.5 to 6.5. PH is an important parameter affecting the growth of microbes during anaerobic digestion. Anaerobic bacteria, especially the methanogens, are sensitive to the acid concentration within the digester and that can be inhibited their growth. Initially weaker pH growth

Observed and after 10^{th} day significant growth observed and it was continued up to the yield of methanogenesis process.

Fig.3 show the variation of biogas production with respect to retention time is precious to acidogenesis and methanogenesis process. In initiate the biogas yield is fewer up to 10^{th} days but after 10^{th} days biogas yield continuously grow. After 20 days the biogas production is rapidly grow at higher rating on mesophilic temperature, C/N ratio = 33:1, pH value =7.9, and moisture content =38%. Beyond 25^{th} days the biogas production constant rate because growth of methanogens slow.

Fig. 4 show variation of biogas production in depends upon the pH value. The digestion of organic compounds is affected by the fermentation constraints such as the biodegradability of substance, the degrading capability of microorganism and the environmental conditions like pH. Primarily the biogas production very slow at the value of pH between the 5.5-6.0 and biogas production constantly grow at pH value between 6-7 but biogas production is rapidly grow at utmost rating the pH value between 7-8.

Fig.5 reveals that the biogas production is influenced by temperature increase. The biogas yield is less between 25-35^{0}C and in the range of 40^{0}C plus the biogas production increasing rapidly because methanogens grow quickly.

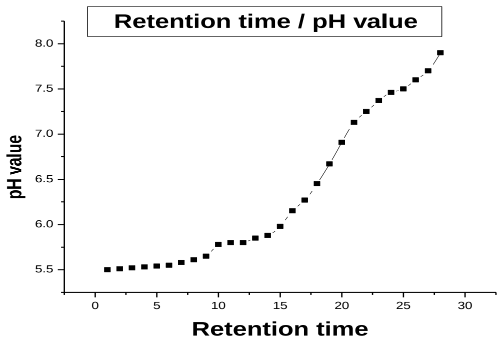

Fig.2 Variation of pH value w.r.t. RT

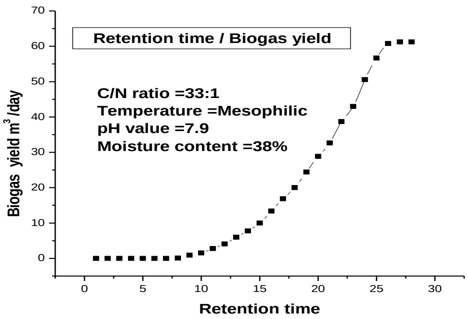

Fig. 3 Variation of biogas yield w.r.t. RT

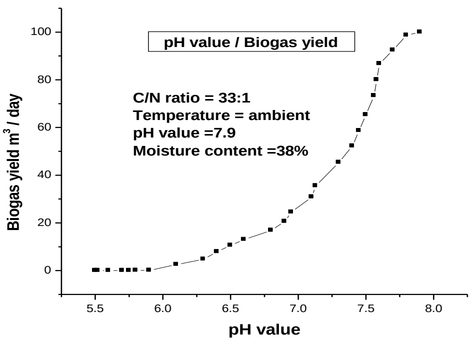

Fig.4 Variation of biogas yield w.r.t. pH

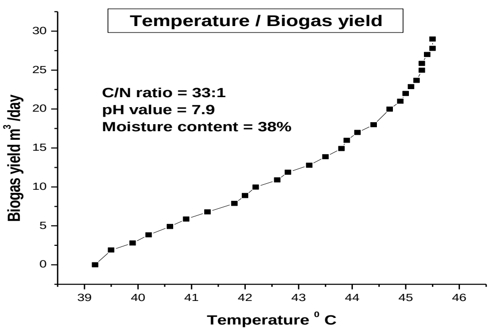

Fig.5 variation of biogas yield w.r.t. temperature

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V. EXPERIMENTAL RESULT

Rate of Biogas production:
The production of biogas was observed and volumes of the biogas collected were recorded during the experiment period 28 days, and the production of biogas was used mainly as an indication of optimum production and the Development of the digestion process.
The daily biogas production rates from the digestions of OFMSW: Cow manure: poultry waste. The co-digestion of 4:1:1 mix OFMSW: CM: PW produced biogas much faster and higher rate per reactor volume than the others co-digestion OFMSW: CM, this maximum rate because mix feed substrate used for this case the readily start up time with digested sludge consume by methanogenic bacteria.
Fig. 6 illustrates the variation of biogas of with respect to retention time, the assessment of biogas production between two Substrate MSW: CM: PW
(4:1:1) and MSW: CM (1:1) at mesophilic temperature. Initially both substrate give higher value it may be because of CO2 generation and later at around 6th day of RT biogas production are comparative same and in the later stage it has been seen that substrate (4:1:1) gives constant growth where as other substrate shows variation it may be because of varied rate of suitable bacteria.

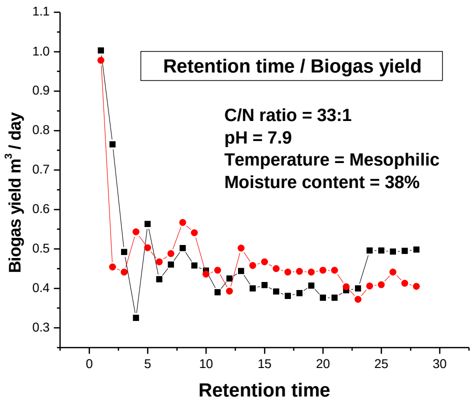

Fig.6 Variation of biogas between two substrate w.r.t. RT

VI. CONCLUSION

In this study the biodegradability of the MSW organic fraction has been studied with different organic fraction at mesophilic temperature zone in two stage anaerobic digestion. It has been seen that the biogas yield in the co-digestion had a higher yield rate and methane content than single substrate with less retention period. The qualitative and quantities analysis reveals that CH_4 varied between 35-59% at a rate of approximately 0.354-0.4 53 m^3/kg VS for different mix 4:1:1 of OFMSW, CM and PW. The present work will help all academicians, rural and urban energy industry people in generating eco-friendly energy and maintaining environment too.

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