Anaerobic Digestion- Reduce, Recycle and Regeneration-A Future Energy Revolution

Mohammad Saleem[a], Manoj Nethala[b], M.Vanisri[c]
[a]Associate Professor, Head of the Dept, Aurora Scientific Technological & Research Academy, Bandlaguda, Hyd, 500 005
[b]Assistant Professor, Aurora Scientific Technological & Research Academy, Bandlaguda, Hyd, 500 005.
[c]Lecturer, JNTU College of Engineeing, Kukatpally, Hyderabad, 500 072.

Abstract

The escalation of Municipal Solid Waste (MSW) has been skyrocketing as an upshot of mounting urban population and industrialization. Day to day augment in waste generation demands Renewable technology for solid waste management for a helpful economic and social extension of the people. All the time people are glancing for the new sources of energy to provoke electricity. Anaerobic digestion is a biological method used to refurbish organic wastes into an unwavering product for different applications such as cooking, electricity generation, etc. with concentrated environmental impacts. The biogas produced can be used as an unusual renewable energy source. Biogas production is an enormous replacement for fossil fuels. This process can also consume MSW for fabrication of electricity. Electricity generation through biogas helps in solving environmental issues, electricity shortage and Solid waste management problem. This paper spotlights on technical possibility and electrical potential mapping of A City through Anaerobic Digestion Technology. The statistical computation has been carried out and total energy potential is deliberate which offers the viability of the Anaerobic Digestion in a City. Total electricity fabrication is 0.8 MW for 24hrs maneuver which can provides 6 Lac units monthly, which fulfils the 10% of total energy necessitate of a city.

KEYWORDS: Anaerobic Digestion, Municipal Solid Waste, Biogas, Carbon Dioxide (Co_2), Methane, Green house gases

I.INTRODUCTION

Bio-energy generated from diversified sources provides local and emerging opportunities to reduce our dependence on foreign oil and petroleum-based fuels. Livestock manure from concentrated livestock operations can be a source of energy production that not only provides an alternative energy source for on-farm use, but mitigates the negative consequences of odor from livestock operations. Biogas generated from manure can be used directly in a gas-fired combustion engine or a micro turbine to create electricity. Additional energy in the form of waste heat from turbine operations can be used to provide heat or hot water for on-farm use, as well as maintain the temperature of a digester during a cold winter.

The current trend of economic growth and standard of living of people increases municipal solid waste (MSW) generation and effects on current landfill scenario, unavailability of land, open burning landfill causes pollution and has greatly effects on public health. There is urgency for an effective solid waste management due to all of these reasons. WTE incineration helps in reducing greenhouse gases (GHGs) by avoiding dumping to landfill, foils the methane emission from landfill and generating renewable energy in form of electricity which further helps in reducing dependency on fossil fuels. In Incineration Technology MSW is combusted in presence of oxygen. Heat produced then utilized to produce steam which turns the turbine and then alternator to produce electricity. Harmful flue gases are treated and then released in atmosphere. By product is utilized in cement factory. In Landfill gas recovery Anaerobic biodegradation results in methane production in landfill which is recovered to produce either electricity or heat. In Biomethanation technology. Organic matter of MSW is converted to biogas by means of anaerobic digestion in presence of methanogenic bacteria. This biogas can further be utilized for cooking or electricity production. In Refuse Derived Fuel technology fuses whole MSW irrespective of individual calorific value of organic and inorganic matter. It forms briquettes and pellets which can be used further as a fuel in many applications. Currently largest source of GHGs emissions in the world are landfills with an assessment of almost 21% of the total methane production. As a GHG Methane is 21 times stronger than carbon dioxide.

II. LITERATURE REVIEW

Mufeed Sharholy et.al (2007)[1]used Arc GIS technique which included MSW sample collection and questioner survey on randomly selected houses and concluded that 45.3% of organic matter and 40% miscellaneous material (glass, paper, plastics etc.) and mentioned the qualitative and quantitative characteristics of MSW for MSWM for developing GIS maps for city of Allahabad. He also explained MSWSM collection, storage and disposal methods. Tsai et.al (2014)[2]did content and chemical analysis of MSW from year 2008 to 2012 with the use of CHP technology and compared the efficiency of plants of Taiwan with different parts of Europe, Germany and Netherlands. He also classified plants on the basis of capacity of waste handling, power generation and efficiency was done and discussed use of district heating and cooling and its use and advantage. S Rathi et.al (2014)[3] used Dulong Formulae heat energy in incineration technology to calculate and analyze potential generation of electricity in Kanpur city of 33MW from MSW of 1200 tonnes/day by considering conversion efficiency, station allowance, unaccounted heat loss and net power generated and classified solid wastes on physical and chemical composition. NIE et.al (2008)[4]explained new technology of circulating fluidized bed and emission of reduction by using equipment such as house filtration, flue gas cleaning and activated carbon in incinerator, adopted by 30 plants for development of China. Biodegradable matter shares 31-36% of total MSW in big cities and 65% in small cities having calorific value of around 5000KJ/Kg. Dioxin emission was limited to 1.0ng TEQ/Nm3. Ojha et.al (2011)[5] explained, classified and compared cities on the basis of population, MSW composition, total waste generated; very big city, big city, medium city, small city and calculated potential of 1700 MW electricity from WTE incineration with some solutions and suggestion to problems occurring in MSWM. Arena et.al (2015)[6]proposed the opinion to solve waste problem as using it as a resource. He explained WTE technology was successful and reliable because of thermal conversion, heat recovery and air pollution technique to reduce health and environmental risk, landfill substitute. Vikash Talyan et.al (2008)[8]discussed first incineration in Delhi, setup in 1989 at Timarpur to produce 3.7MW from 300 Tonnes of waste of calorific value higher 1000 Kcal/Kg but was closed in 21 days only due to falling of calorific value.

First composting plant was setup in 1980 in Okhla and was shut down due to absence of market and high production cost. He explained three landfills in at Gazipur, Okhla and Bhalswa with LFG potential of energy generation 12.98*105 Kwh/year. Ityona Amber et.al (2012)[7] calculated potential generation of 700KWh/tonne of electricity with calorific value of 17.23 MJ/Kg and conversion efficiency of 25% from incineration technology in Nigeria by considering methodology of analyzing 5 samples of 10 Kg each of waste and evaluated that 43% of total MSW organic components are present while 8% are paper, cardboard, plastics. V G Sister (2006)[9] simulated plant model to improve the performance of waste incineration plant by considered gas turbine and steam cycle heat from outgoing fuel gases which resulted in efficiency of binary system gas incinerator of 42-45%.

III. THE ANAEROBIC DIGESTION PROCESS

Anaerobic digestion, or the decomposition of organic matter by bacteria in the absence of oxygen, occurs naturally in liquid manure systems. The lack of oxygen and abundance of organic matter in liquid manure provide the proper conditions for anaerobic bacteria to survive. Unfortunately, uncontrolled anaerobic decomposition can cause the foul odors sometimes associated with liquid manure storage and spreading. The effluent remaining after controlled anaerobic decomposition, equal in volume to the influent material, is liquefied, low in odor, and rich in nutrients. This digested material is biologically stable and will resist further breakdown and odor production when stored under normal conditions.

Anaerobic bacteria transform manure and other organic material into biogas and a liquefied effluent during the three stages of biogas production (Figure 1). In the liquefaction stage, liquefying bacteria convert insoluble, fibrous materials such as carbohydrates, fats and proteins into soluble substances. However, some fibrous material cannot be liquefied and can accumulate in the digester or can pass through the digester intact. Most of the liquefied, soluble compounds are converted to biogas by the acid- and methane-forming bacteria during steps 2 and 3 of biogas production. In the second stage of anaerobic digestion, acid-forming bacteria convert the soluble organic matter into volatile acids—the organic acids that can cause odor production from stored liquid manure. Finally, methane- forming bacteria convert those volatile acids into biogas—a gas composed of about 60 percent methane, 40 percent carbon dioxide, and trace amounts of water vapor, hydrogen sulfide, and ammonia. Not all volatile acids and soluble organic compounds are converted to biogas; some become part of the effluent.

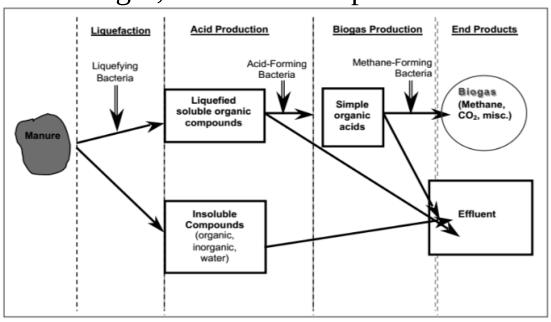


Fig.1. Schematic diagram of the stages of anaerobic digestion process

Anaerobic Digestion (AD) occurs when organic material decomposes biologically in the absence of oxygen. This process releases biogas while converting an unstable, pathogen-rich, nutrient-rich organic substrate like manure into a more stable and nutrient-rich material with a reduced pathogen load (Fig.2). Biogas is composed of approximately 65% methane with the remaining content being mostly carbon dioxide and other trace gases (Jones, 1980).The left over, more stable substrate can be a good source of fertilizer, or in some cases, further composted and reused as a bedding material.

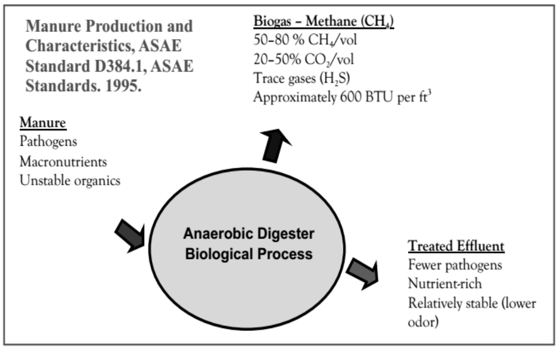
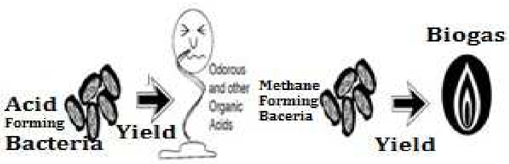


Fig.2. Schematic of basic process of anaerobic digestion

Three Stages of Biogas Production.

Methane-forming bacteria are more sensitive to their environment than acid-forming bacteria. Acid-forming bacteria can survive under a wide range of conditions while methane-forming bacteria are more demanding (Figure 2). Under the conditions typical of liquid manure storages, more acid-forming bacteria can survive than methane- forming bacteria. Therefore, acids are formed and are not converted to biogas. This excess of volatile acids can result in a putrid odor. In a controlled, optimum environment, methane-forming bacteria survive and convert most of the odor-producing volatile acids into biogas. Conditions that encourage activity of both acid- and methane-forming bacteria include:

- ❖ An oxygen-free environment
- ❖ A relatively constant temperature of about 95℉
- ❖ A pH between 6.6 and 7.6



Anaerobic Digestion System

An anaerobic digestion system (Figure 3) can provide an optimal environment for controlled anaerobic digestion. A typical system consists of liquid manure handling equipment, a heated anaerobic digester, gas utilization equipment, safety equipment, and effluent storage and handling systems. The anaerobic digestion system is an addition to the manure handling scheme—a step for manure processing between the barn and the storage facility. It does not replace any part of a typical manure handling system.

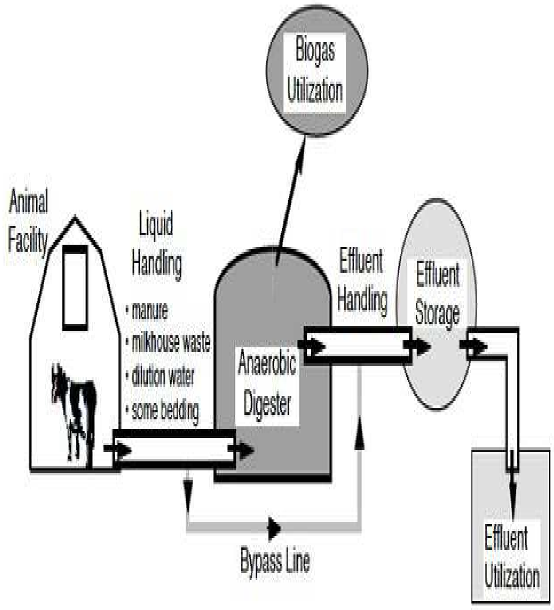


Fig.4. Schematic Diagram of the Typical Anaerobic Digestion System

Potential Advantages of Controlled Anaerobic Digestion include substantially less odor with digested manure than there is with stored liquid manure. Energy produced from biogas offsets the cost of the investment. The nutrient content of digested manure is equal to that of raw manure. Digested manure is more liquefied than raw manure, making it easier to pump long distances. Digested manure is biologically stabilized, making it easier to store for long periods without odor problems. Homogenous digested manure performs well in liquid application systems. Rodents and flies are less likely to be attracted to digested manure. Emissions of methane from liquid manure storage areas are reduced.

IV.AMOUNT OF WASTE GENERATED

The city generates, on an average, about 200MT of MSW per day. The major sources of MSW generation of the city are domestic, shops and commercial establishments, hotels, restaurants, dharamsalas and fruit and vegetable markets.

Feed Stock	Total Solids TS (%)	Volatile Solids (% if TS)	C:N Ratio	Biogas Yield (m^3, kg^{-1},VS)	Retention Time (Days)	CH_4 Content	Unwanted Substances	Inhibiting Substances	Frequent Problems
Pig Slurry	3-8[d]	70-80	3-10	0.25-0.50	20-40	70-80	Wood shavings, bristles, H_2O, sand, cords, straw	Antibiotics, disinfectants	Scum layers, sediments

Cow Slurry	**5-12[d]**	**75-85**	**6-20[a]**	**0.20-0.30**	**20-30**	**55-75**	**Bristles, soil, H_2O, NH_4+,straw,wood**	**Antibiotics, disinfectants**	**Scum layers, sediments**
Chicken Slurry	**10-30[d]**	**70-80**	**3-10**	**0.35-0.60**	**>30**	**60-80**	**NH_4+, grit, sand, feathers**	**Antibiotics, disinfectants**	**NH_4+-inhibition Scum layers**
Whey	**1-5**	**80-95**	**n.a**	**0.80-0.95**	**3-10**	**60-80**	**Transpiration impurities**		**pH-reduction**
Fermented Slops	**1-5**	**80-95**	**4-10**	**0.35-0.55**	**3-10**	**55-75**	**Undegradable fruit remains**		**High acid concentration, VFA-inhibition**
Leaves	**80**	**90**	**30-80**	**0.10-0.30 [b]**	**8-20**	**n.a**	**Soil**	**Pesticides**	
Wood Shavings	**80**	**95**	**511**	**n.a**	**n.a**	**n.a**	**Unwanted material**		**Mechanical problems**
Straw	**70**	**90**	**90**	**0.35-0.45 [e]**	**10-50 [e]**	**n.a**	**Sand, grit**		**Scum layers, poor digestion**
Wood Wastes	**60-70**	**99.6**	**723**	**n.a**	**n.a**	**n.a**	**Unwanted material**		**Poor anaerobic biodegradation**
Garden Wastes	**60-70**	**90**	**100-150**	**0.20-0.50**	**8-30**	**n.a**	**Soil, cellulosic components**	**Pesticides**	**Poor degradation of cellulosic components**
Grass	**20-25**	**90**	**12-25**	**0.55**	**10**	**n.a**	**Grit**	**Pesticides**	**pH-reduction**
Grass Silage	**15-25**	**90**	**10-25**	**0.56**	**10**	**n.a**	**Grit**		**pH-reduction**

Fruit Wastes	**15-20**	**75**	**35**	**0.25-0.50**	**8-20**	**n.a**	**Undegradable fruit remains, grit**	**Pesticides**	**pH-reduction**
Food Remains	**10**	**80**	**n.a**	**0.50-0.60**	**10-20**	**70-80**	**Bones, plastic material**	**Disinfectants**	**Sediments, mechanical problems**

V. CALCULATION OF ENERGY POTENTIAL

Only biodegradable fraction of total waste can be digested to produce gases so total amount of waste needs to be taken to generate 220 gm of CH_4 and 512.6 gm of CO_2 will be:

$$C_{25.41}H_{39.88}O_{14.25}N + 9.06\,H_2O = 13.75\,CH_4 + 11.65\,CO_2 + NH_3$$

Total amount of waste *0.65 = 573.8 (mass of hydrocarbon)
Total Amount of Waste = 882.76 gm
Weight of CH_4 = (220/882.76)*22.39 = 5.57 Kg
Weight of CO_2 = (512.6/882.76)*22.39 = 13 Kg
Density of CH_4 and CO_2 are taken as 0.7167 g/l and 1.9768 g/l respectively.
Volume of CH_4= (5.57 / 0.7167) = 7.77 m^3
Volume of CO_2 = (13 / 1.9768) = 6.57 m^3
Total Volume of gas generated = 7.77+6.57=14.34 m^3
Percentage of CH_4 = (7.77/14.34) * 100 = 54.18 %
Percentage of CO_2 = (6.57/14.34) * 100 = 45.82 %
Amount of gas generated per kg = 14.34/100 = 0.1434 m^3/Kg.
Amount of waste generated in Haridwar City = 200000 Kg per day
Therefore, total biogas generated = 200000 * 0.1434 = 28680 m^3/day
Considering 60% digestion efficiency = 0.6*28680 = 17208 m^3/day
Net Calorific Value of Biogas = 5000 Kcal/m^3
Energy Potential = 5000 *17208 * 0.00116 = 99806.4 KWH
Power Generation = 99806.4/24 = 4158.6 KW
Conversion Efficiency (30 %) = 0.3 * 4158.6 = 1247.58 KW.
Considering Heat Loss (35 %) so net output = 0.65 *1247.58 = **0.8 MW**

VI. RESULTS & DISCUSSION

The numerical computation has been carried out and following total energy potential is calculated which provides the feasibility of the Anaerobic Digestion in A City. Total electricity production is 0.8 MW for 24hrs operation which can provides 6 Lac units monthly, which fulfils the 10% of total energy need of a city.

CONCLUSION

It is a great step towards sustainable development as it saves coal resources which can be used by future generation while eliminating solid waste management problem which solves the land shortage problem and that extra land can be used to any fruitful work without Solid Waste Management that land is wasted as huge piles of solid waste just cover land making them useless and toxic. Also leach ate problem is solved by waste management as open dump cause leach ate to develop which even pollutes the underground water. None of the single solution is capable of solving the entire solid waste management problem, although by favorable use of methodology of combined technologies- decrease at source, reutilizing, composting and incineration can be supportive. Decreasing the waste generation at source level only. Recycling & reprocessing new materials from used matter like paper, plastics, metals, glass, etc. By decomposing organic matter like kitchen waste, food waste in aerobic or anaerobic way compost can be prepared which further can be utilized as a fertilizer for soil. Combustion of waste in presence of air at high temperatures in Incinerator technology, it lowers the volume of waste up to 90%. Therefore, landfill can be avoided completely by above technologies. But from decades in India definition of energy means electricity and scarcity of electricity creates hindrance to growth and development so Anaerobic Digestion should be used for solid waste management as it provides all kind of process- reduce, recycle and regeneration.

REFERENCES

[1]. MufeedSharholy, k. A. (2007). Municipal solid waste characteristics and management in Allahabad, India. Waste Management, 490-496.

[2]. Tsai, W.-T. (2014). Analysis of Municipal solid waste incineration plants for promoting power generation efficiency in Taiwan. Master Cycles Waste Management.

[3]. S Rathi, D. P. (2014). Electrical Energy Recovery from Municipal Solid Waste of Kanpur City. International Journal of Scientific Research Engineering & technology (IJSRET), 923-929.

[4]. NIE, Y. (2008). Development and prospects of municipal solid waste (MSW) incineration in China. Environment Science Engineering China, 1-7.

[5]. Ojha, K. (2011). Status of MSW management system in northern India-an overview. Environmental Development Sustainable, 203-215.

[6]. Arena, U. (2015). From waste-to-energy to waste-to-resources: The new role of thermal treatments of solid waste in the Recycling Society Waste Management.

[7]. Ityona Amber, D. M. (2012). Generation, characteristics and energy potential of solid municipal waste in Nigeria. Journal of Energy in South Africa, 47-51.

[8]. VikashTalyan, R. P. (2008). Status of municipal solid waste management in Delhi, the capital of India. Waste Management, 1276-1287.

[9]. V G Sister, L. V. (2006). Ways of improving the performance of energy producing equipment at waste incineration plant. Chemical and Petroleum Engineering, 3-4.