OPEN ACCESS INTERNATIONAL JOURNAL OF SCIENCE & ENGINEERING

BIOMASS: A SUSTAINABLE ALTERNATIVE FOR SOLID WASTE MANAGEMENT

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***Abstract*: India, as an emerging economy, is facing the challenges of the rapid and uncontrolled urbanization. Production and subsequent management of municipal solid waste has been emerged as a major challenge for the various stakeholders. A major component of municipal solid waste is biomass that can be utilized to produce electricity which in turn reduces the load on Municipal Corporation. Study shows that most of the solid waste is discarded illogically in open dumps which pose a major concern to public health and environment. The unhygienic disposal of animal biomass could result into a serious health concern due to spread of many pathogens via various environmental matrices. The present study reviews the various concerns and methods used for the sustainable utilization of biomass solid waste.**

Keywords: *Biomass, municipal solid waste, anaerobic digestion.*

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I INTRODUCTION

India is the fastest growing economy in the world. Last year India's economy grew by 7.6% and it is estimated that it will reach 8% by 2019 [1]. The uncontrolled rapid urbanization and subsequent establishment of heavily populated metropolitan cities, has resulted into the production of million tons of the waste every day [2]. The safe and effective management practices for the disposal of this huge waste has been emerged as a big challenge for various governmental bodies and the civil societies. Traditionally, solid waste management practices consist of collection, transportation, segregation, processing and disposal. This whole process is normally carried out by the untrained worker that makes them prone to various kinds of health hazards. Disposal of poorly segregated solid waste at various landfill sites poses serious threat to local air quality, surface water and ground water qualities. Although, worldwide many techniques have been in use for the effective disposal and utilization of solid waste, there is an urgent need for the cost-effective technology for sustainable solid waste management.

India's population is growing very rapidly and so the waste generated by them, and a big portion of this waste is biomass which can be used as a source of energy. This waste can be used to generate biogas which can be used directly or can be used as a source to produce electricity. In the past few decade's interest in the biomass use as a renewable energy resource has been renewed source because of technological advancement in crop production and conversion efficiency [3][4].

Present paper deals with the various concerns and techniques used for sustainable utilization of biomass solid waste in Indian scenario. Data used for available techniques and biomass availability is updated to latest figures as far as possible.

A. *Solid waste management in India*

With rapid urbanization and increasing population India is facing a major challenge of solid waste management. The solid waste collected by municipal authorities is disposed in open dump yards haphazardly, if this waste is disposed in such a way then it can cause ecological imbalance. The best way to manage the waste is to segregate it, recover resources from this and finally the leftover can then be recycled by various techniques. At present India's urban population generates more than one lakh tonne waste every day of which less than 10 megacities generates more than 18% of waste [5]. Municipal solid waste contains about 30-55% of biodegradable waste which depends on the food habits of the people living there. The percentage of recyclable material varies from 5-10% and the rest is inactive material which cannot be used for any purpose and is sent to the landfill [6]. A large portion of municipal solid waste contains biomass. Biomass refers to living or recently dead animals and any by-product of these organisms, plants or animals. It can be used

directly or can be converted to some usable form such as biogas, bio-fuel, bio-products etc. In India, most of the people work in farming and related activities. So there is no shortage of biomass in India. If this biomass is used for power generation then it will serve various purposes:

- The problem of waste disposal will be resolved to a larger extent and would clean our environment. Thereby spreading of diseases from waste can be minimized.
- It will be a continuous source of energy as it will not deplete with its use as is the case with fossil fuels.
- It is present almost everywhere so we need not transport it from one place to another.
- Electricity produced from biomass is available at cheaper rates.

Waste can be seen everywhere in cities and villages of India, in streets, plots, sewage etc. The main reasons responsible for this are:

- When townships are designed , no attention is given to waste management
- Shortage of staff
- Lack of awareness among people
- Less funds are allocated

Generally, less economically developed counties have poor management of waste due to lack of infrastructure [7].

II BIOMASS WASTE TO ENERGY

Biomass conversions can be tailored to rural or urban environments that would contribute to waste management's and bio-energy generations which can be utilized in domestic, commercial or industrial applications. Biomass has vast potential and can be obtained from various sources which are never ending resources. Today, a number of technologies are available that can extract energy efficiently from these resources

A. Biochemical methods

Biochemical method is the use of micro-organisms, enzymes to produce methanol. These organisms are used as biocatalysts for the conversion of organic waste into energy. These processes not only produce biogas but other material also which is rich in nutrients and can be used as fertilizer.

A.1. Anaerobic digestion

Anaerobic digestion is a collection of biological processes in which organic matter is breakdown to produce energy in the form of a gas called biogas, this gas can be used directly for cooking or heating application or can be used as a fuel in power stations. Although the gas produced contain a large portion of carbon dioxide and traces amount of other gases such as H_2S, H_2 etc which are responsible for the low calorific value and bad smell of the biogas but these can be easily removed by passing the solution from lime water or simply by water scrubbing. This process occurs in bio-digesters (airtight reactors) in three steps, in the first step a group of bacteria (such as cellulose decomposing bacteria) act upon the organic matter and break it to make available for other bacteria. The process of breaking down large polymers into smaller monomers is called enzymatic hydrolysis. For example, proteins are converted into peptides (amino acids), fats into fatty acids and carbohydrate into glucose and fructose. In the second step acid forming bacteria converts these sugars and amino acids to CO_2, H_2, NH_3, and organic acids such as acetic acid. In the final step methanogens produce methane either by reducing CO_2 or by fermenting the acids. When the parameters are under control these the microorganisms can convert more than 80% of the substrate into biogas [8].

There are several benefits of anaerobic digestion but the main benefit is that it does not pollute the environment and reduce Green House Gas emission by diverting the waste biomass to digesters instead of dumping it which may directly release the methane into the atmosphere. With several benefits it has some drawbacks also. For instance, we need to pre process the raw material for the smooth running of the digester and it treats only the organic content of the Municipal Solid Waste. Although well designed digesters help to reduce the odour but it can be released during handling of the biomass. Figure 3.1 shows anaerobic digestion in a digester.

A.2. Ethanol fermentation

Fermentation is a process in which microorganisms such as yeast and bacteria convert sugars into alcohol, gases or acids. Yeasts functions generally in the presence of oxygen but they can also work in anaerobic condition i.e. in the absence of oxygen. When anaerobic conditions prevail then alcohol fermentation occurs, therefore it is considered as anaerobic process. This process completed in two steps.

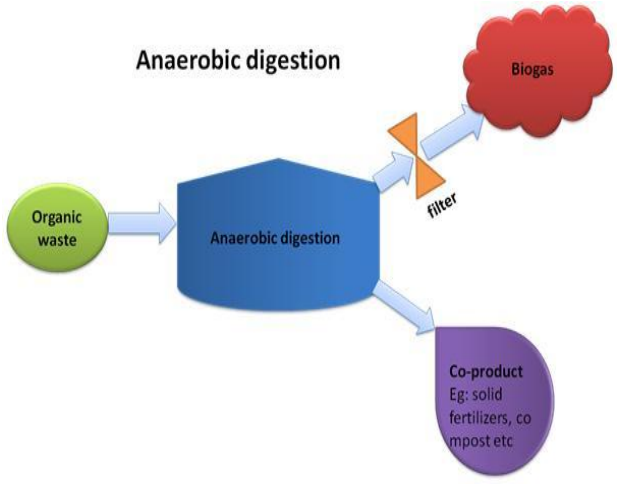

Figure 3.1 The schematic diagram of the anaerobic digestion

In the first step, yeast act upon glucose (a type of sugar) and break it to form pyruvate (amino acid) molecules.

This process is termed as glycosis.In the second step, these pyruvate molecules are converted to ethanol and carbon dioxide.This process is called as ethanol fermentation. Zymase is the enzyme which helps in the conversion of pyruvic acid to ethanol and carbon dioxide.

The benefit of using this process of making ethanol is that it is produced from renewable resources i.e. sugars which can be produced from plants and this process does not produce any extra carbon in the atmosphere because takes in CO_2 during its growth. Another benefit is that it can be carried out at room temperature so it is cost effective because we need not to supply any extra energy for the process to occur. The drawback is that the ethanol produced is not pure so we require another process for its purification. Also, after reaching a certain concentration of about 15% the yeasts start dying which ceases the fermentation process. One major drawback is that this is a batch process so ony small amount can be produced in a given time [9].

A.3. Methane from landfills

Methane is very strong green house gas which has as much as 30 times more the potential than CO_2 of absorbing low frequency radiation. Today most of the methane accumulated in the atmosphere is derived from these landfill sites.

Methane leaks from landfills generally by two paths either directly to the atmosphere or by a process called diffusion through the cover soil. Therefore instead of letting it to the atmosphere we can trap this gas and use it for various purposes. The extraction of landfill gas is a difficult process because it requires drilling of holes into the landfill sites to extract it. The disadvantage of producing methane from landfills is that it contains methane gas as well as many other non methane organic components like mercury and radioactive contaminants like tritium which can be highly toxic.

B. Thermo- chemical methods

These are the technologies in which the energy from biomass is extracted by the application of heat and chemicals. Thermo chemical processes involve various stages. In the first stage the the solid biomass is converted into gas, after that the gas is cooled and condensed into oils and in the last stage it is modified to produce syngas. This syngas can be upgraded to form biodiesel, lubricants and ammonia. Different technologies for conversions are:

B.1 Pyrolysis

Pyrolysis is the decomposition of organic waste material at high temperature in the absence of oxygen. With the increase in temperature the process of decomposition also increases. So in industries the temperatures used are greater than 400^0C. Pyrolysis involves simultaneous change of chemical composition and the physical state. This process produces two important products, biochar (a type of charcoal) and coke, it also produces tar (a liquid). Pyrolysis is again classified as slow pyrolysis and fast pyrolysis. In slow pyrolysis the temperature is increased slowly at the rate of approximately .5 to 2^{o}C per second to about 500^{o}C. In this process we mostly get tar and char whereas in fast pyrolysis process the temperature rapidly increases from about 600^{o}C to about 1000^{o}C. In this process we get char in large quantities. The advantage of pyrolysis is that the gases and vapours formed after converting the organic material is easy to handle, it also help in the recycling of the plastic that is mixed in the waste which is difficult to recycle efficiently by other means. The disadvantages of pyrolysis are that the external heat is required for the decomposition of organic waste to produce syngas and in the end product the sulphur contents are relatively high. Figure 3.2 shows the process of pyrolysis.

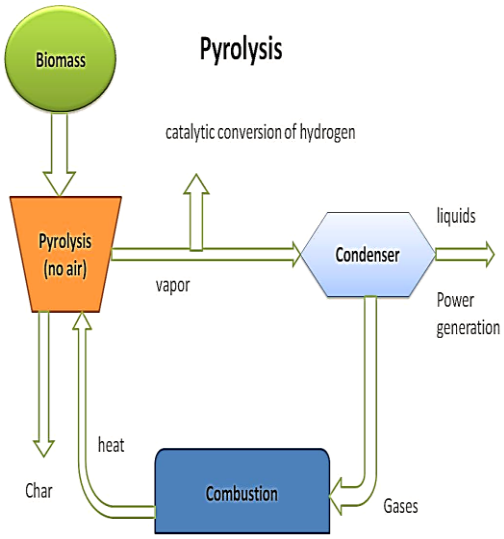

Figure 3.2 Schematic diagram of Pyrolysis

B.2. Gasification

Gasification is a process in which organic waste is converted into syngas (synthetic gas). By varying the condition the proportion of the components in the syngas can be controlled. Before feeding the organic waste, metals and plastics should be removed from it. This process involves five steps: drying (by giving heat to biomass), pyrolysis (to make charcoal), combustion and cracking, and reduction (to convert charcoal into a flammable gas). Different processes of gasification require different temperatures. For example, we need about 150^0C for drying and about 800^0C for converting charcoal into flammable gas.

The benefit of gasification is that emission control is easy because the gas produced is at a higher pressure and temperature. At higher temperature oxides of nitrogen and sulphur can be removed easily. The drawback of gasification is that it is costly as well as a complex process, also for the continuous operation we need frequent refueling. Handling and disposal of residues such as ash, tarry condensates is

again a challenge [10]. Figure 3.3 shows process of gasification.

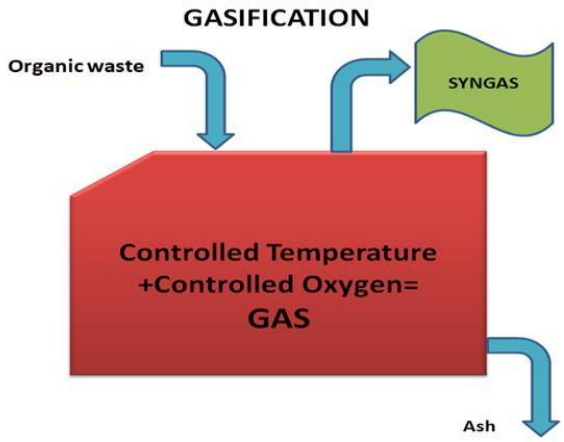

Figure 3.3 Schematic diagram of Gasification

B.3. Catalytic liquefaction

Catalytic liquefaction is a technology used to produce chemicals and liquid fuels from the organic matter. The products produced have greater energy density. The process is carried out in liquid phase at high temperature and pressure. It requires heating the material in the atmosphere of high hydrogen pressure and sometimes a catalyst. Some more research is required to overcome the technical problems of this technology.

III ENVIRONMENTAL AND HEALTH CONCERNS

The production and use of energy has environmental consequences at local as well as global level. Renewable energy sources are cleaner than fossil fuels but they are not totally free from pollution. The use of biomass as an energy resource has potential impacts on the environment. The severity of the impact depends on various parameters and consequences may vary considerably. The localized effects may be soil disturbance, nutrition depletion, water pollution and also pathogenic infection on human beings. The environmental implications at global level may be in the form of Methane emission. Various environmental potential threats are as follows:

A. Air pollution

Burning Biomass wood and other biological material directly to get energy emits as much pollution as burning fossil fuels. The gases emitted by these are generally irritants or asphyxiants and the gas hydrogen sulphide is produced during anaerobic digestion of biomass is poisonous. The Other contentious issue with the production of biogas is the order which may be a cause of tension, anger and depression to the people and to the animals [11].

B. Explosion

When dealing with methane (a product of anaerobic digestion) which makes up more than 60% of biogas, forms explosive mixture in air which might get explode if naked flames are used in the vicinity of digester. Other sources can also cause explosion like Spark in Electrical switches, static electricity etc [12].

C. Soil and water contamination

Biogas digester slurry has high content of water and if earthen pits are used for this then it finds its way deep into the ground and contaminate the ground water and drinking water sources nearby. Generally, these contaminants contain heavy metal such as Hg, Zn, Cd, Pb, Cu etc. which are hazardous to human health even if taken in small quantities [13].

D. Pathogens

Digester may become a source of pathogens if it is it is not properly operated. The handling of cattle dung and night soil for production of biogas presents a potential threat to human health. These pathogens are originated from ruminants of goat, sheep camel, cow etc. Therefore, the animal waste must be handled with utmost care to limit the pathogenic contamination.

IV CONCLUSION

India has a great potential for waste to energy technologies, which not only meet the energy demand of such a big economy but also solve the issue of municipal solid waste. Great opportunities exist for the optimized biochemical processes such as anaerobic digestion, gasification, pyrolysis and catalytic liquefaction for the production of energy in India. These biomass plants not only clean the environment but also solve electricity problem of rural areas. Above discussion shows that if biomass is not used wisely then it may be another source of pollution. We need some norms for the efficient utilization of biomass and a thorough research is required to increase the efficiency of these conversion processes. There is an urgent need of proper legislation for the scientific utilization of solid waste resources.

ACKNOWLEDGMENT

Authors of the paper would like to thank Dr Sudeep Shukla, ASEES, Amity University and Dr Subhra Das, ASAS, Amity University Haryana for their continuous support and motivation. We are thankful to Amity University for providing the necessary resource for this study.

REFERENCES

[1] Lea, R. (2017). The Eurozone economy: steady, if unspectacular, growth and higher inflation. *Arbuthnot Banking Group*, *27*.

[2] Pappu, A., Saxena, M., & Asolekar, S. R. (2007). Solid wastes generation in India and their recycling potential in building materials. *Building and Environment*, *42*(6), 2311-2320.

[3] Shukla, P. R. (1997). Biomass energy in India: transition from traditional to modern. *The Social Engineer*, *6*(2), 1-21.
[4] Kumar, S., Singh, S. P., Mishra, I. M., & Adhikari, D. K. (2009). Recent advances in production of bioethanol from lignocellulosic biomass. *Chemical Engineering & Technology*, *32*(4), 517-526.
[5] Mor, S., Ravindra, K., De Visscher, A., Dahiya, R. P., & Chandra, A. (2006). Municipal solid waste characterization and its assessment for potential methane generation: a case study. *Science of the Total Environment*, *371*(1), 1-10.
[6] Narayana, T. (2009). Municipal solid waste management in India: From waste disposal to recovery of resources?. *Waste management*, *29*(3), 1163-1166.
[7] Ravindranath, N. H., Somashekar, H. I., Nagaraja, M. S., Sudha, P., Sangeetha, G., Bhattacharya, S. C., & Salam, P. A. (2005). Assessment of sustainable non-plantation biomass resources potential for energy in India. *Biomass and Bioenergy*, *29*(3), 178-190.
[8] Sharma, S., Meena, R., Sharma , A., Goyal, P. K. (2014). Biomass Conversion Technologies for Renewable Energy and Fuels: *A Review Note. IOSR Journal of Mechanical and Civil Engineering*, 11(2), 28-35
[9] Wang, J., Chae, M., Sauvageau, D., & Bressler, D. C. (2017). Improving ethanol productivity through self-cycling fermentation of yeast: a proof of concept. *Biotechnology for biofuels*, *10*(1), 193.
[10] Decker, S. R., Sheehan, J., Dayton, D. C., Bozell, J. J., Adney, W. S., Aden, A., ... & Lin, C. Y. (2017). Biomass conversion. In *Handbook of Industrial Chemistry and Biotechnology* (pp. 285-419). Springer, Cham.
[11] Ward, T. J., Semmens, E. O., Weiler, E., Harrar, S., & Noonan, C. W. (2017). Efficacy of interventions targeting household air pollution from residential wood stoves. *Journal of Exposure Science and Environmental Epidemiology*, *27*(1), 64-71.
[12] Shen, X., Zhang, B., Zhang, X., & Xiu, G. (2017). Explosion characteristics of methane-ethane mixtures in air. *Journal of Loss Prevention in the Process Industries*, *45*, 102-107.
[13] Galitskaya, I. V., Mohan, K. R., Krishna, A. K., Batrak, G. I., Eremina, O. N., Putilina, V. S., & Yuganova, T. I. (2017). Assessment of soil and Groundwater Contamination by Heavy Metals and Metalloids in Russian and Indian Megacities. *Procedia Earth and Planetary Science*, *17*, 674-677.

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