Review Article

An overview on prospects of Organic waste: The promising Fuel of future

Abstract-Organic wastes can come straight from the source or be derived from MSW (Municipal Solid Waste) or food processing waste. Municipal organic waste primarily consists of lignocelluloses. It is widely known that the high stability of the components makes lignocellulose hydrolysis ineffective. Environmentally acceptable and effective alternatives to landfilling and incineration for the treatment of organic pollutants include thermal disintegration and biological treatment methods. However, the qualities of the waste also play a role in this. Anaerobic digestion, followed by aerobic stabilisation, biogas production, and anaerobic digestion allow for the co-generation of electrical and thermal energy as well as the manufacture of premium natural fertiliser. Enzymatic hydrolysis is the initial stage of a valorisation process to improve the production of fuels through fermentations. In this regard, MOW pre-treatment is essential to boost the effectiveness of biological processes.

In this paper, several organic wastes, pre-treatment processes and microbial degradation techniques are reviewed and analysed. Also, the limitations of various techniques are pointed out. The fundamental scientific features are highlighted and details are given on the technological parameters. An insight towards challenges faced in biodegradation of lignocellulosic waste material is provided. Researches reveal the fact that there is vast hope in the availability of sugars after pre-treatment which may be very crucial for biofuel generation.

Key words:

Municipal organic waste, Lignocellulose, Biodegradation, Enzymatic, Fermentation

1.Introduction

Waste materials which arise in association with diverse human activities is a major threat to the sustainable utilization of natural resources that is air, water, soil, and natural scenery ***(Basnet , 1993)***. This waste is produced by several sectors including industries, forestry, agriculture and municipalities ***(Taherzadeh , 2008).***

Waste can be classified as following

On the basis of state
- Solid
- Liquid
- Gaseous

On the basis of source
- Domestic
- Industrial
- Medical
- Agricultural
- Vehicle emissions
- Electronic

On the basis of degradation
- Biodegradable
- Non biodegradable

On the basis of environmental impact
- Hazardous
- Non hazardous

On the basis of composition
- Organic
- Inorganic

Energy can be derived from waste that has been treated by many ways ranging from pressing into solid forms to incineration ***(Debirmas et al., 2011).*** Organic waste account for most of the waste created in nature which then directly affects the urban living system. Biological treatments are among the most convenient and effective method for treating organic waste.

2. Need for Waste Management

The primal approach towards waste should be to generate as less waste as possible. However, in a rapidly growing and urbanizing world it is a difficult task. Hence a proper waste management system is required to cope up.

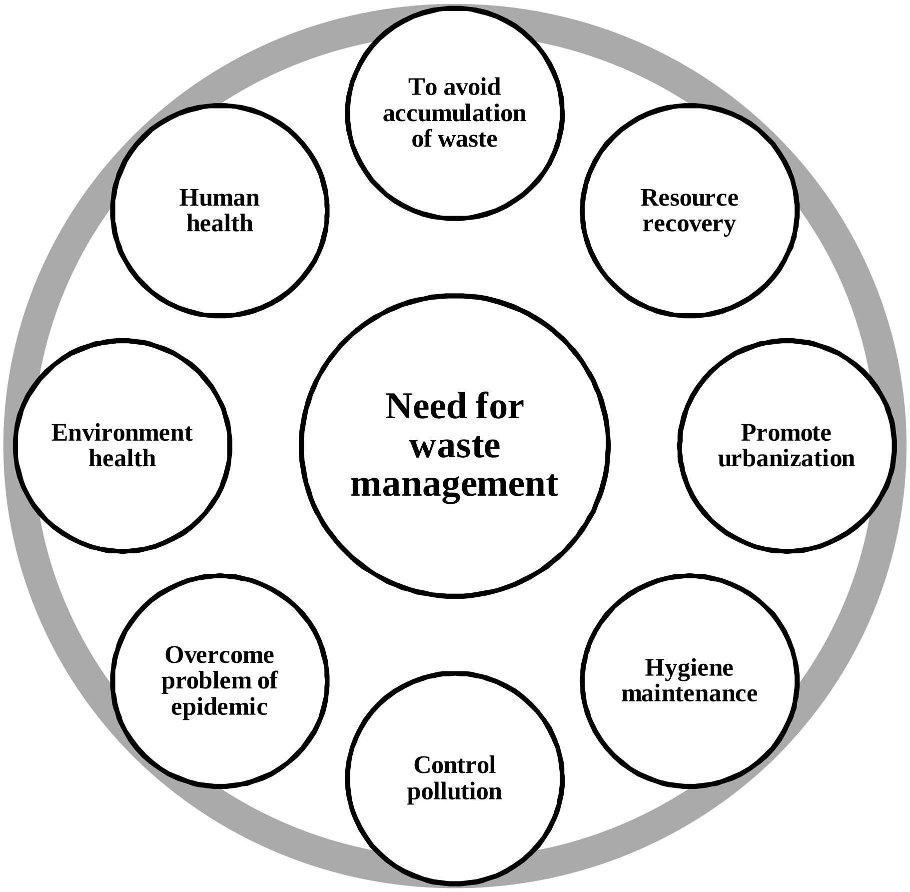

FIGURE 1- Need for waste management

3. Organic Waste

The **Food and Agriculture Organization (FAO)** defines food waste as food that is discarded, generally at retail and consumption stages ***(Liu et al., 2016).*** Every year, more than 2.1 billion tonnes of municipal solid trash are produced worldwide, yet only approximately 16% of that waste is recycled, and more than 46% of it is thrown away. Food waste disrupts global food systems and, if toxic waste, poses a threat to human health, biodiversity, and ecosystems ***(Hemidat et al., 2022).***

Future feedstocks will likely be mostly produced from primary residues and energy crops, collectively referred to as "**green wastes**", in addition to more readily biodegradable materials such simple saccharides, starch, and cellulose. This is because it contains a significant amount of microbially converted carbohydrates. For instance, the dry weight proportion of woody waste is approximately 70% carbohydrates (cellulose and hemicellulose), and 25–35% lignin. The lignin covers the polysaccharides that are substrate for enzymes or/and microbes to convert into fuel sources ***(Take et al., 2016).***

4. Impact of waste management

Straws, nuts, seeds, fruit shells, fruit seeds, plant stalks, green leaves, and molasses are examples of agricultural wastes that have the potential to be used as renewable energy sources. Each year, huge amounts of agricultural plant leftovers are produced worldwide, yet they are rarely used ***(Demirbas, 2011).*** The amount of organic waste in solid garbage declines as a country's income level rises; whereas it is 64% in low-income countries, it is only 28% in high-income nations. ***(Lim et al., 2016).***

Guidelines and directives to reduce waste generation and promote waste recovery are laid down according to the "**waste management hierarchy**", in which waste prevention, reuse, recycling and energy recovery are designed to minimize the amount of waste left for final, safe disposal ***(Isa et al., 2004).***

FIGURE 2-Waste management hierarchy

Education and awareness in the area of waste management is very important from a global perspective of resource management. Sustainable waste management aims to reduce the amount of waste that is discharged into the environment by reducing the amount of waste generated. Waste is generally dumped in open areas far from the city or burned in open fires, which results in pollution .This can be overcome by public education. Educating personnel will also improve the efficiency of the waste management system and minimize its possible health and environmental risks. Improper management of wastes can lead to serious health threats as a result of fires, explosions, and contamination of air, soil, and water and pose threats to those living in nearby communities and can result in costly clean-ups ***(Demirbas,2009; Cardak, 2009; Kecebas&Alkan,2009; Saidur , 2010; Tatli , 2009).***

4.1 Landfills

Landfilling is the oldest method of waste disposal by burial, typically used throughout the world. It is the most cost-efficient method in which the decomposition of biological waste occurs via microbes. Waste decomposition results in the production of biogases, mainly methane and carbon dioxide ***(Idehai, 2015).*** These gases, if released into environment, cause **Global warming** (methane is nearly 20 times more effective than carbon dioxide at trapping heat in the atmosphere). This problem can be solved, and can generate revenue, if landfills include a **Gas collection system*(Dada &Mbohwa , 2017).***

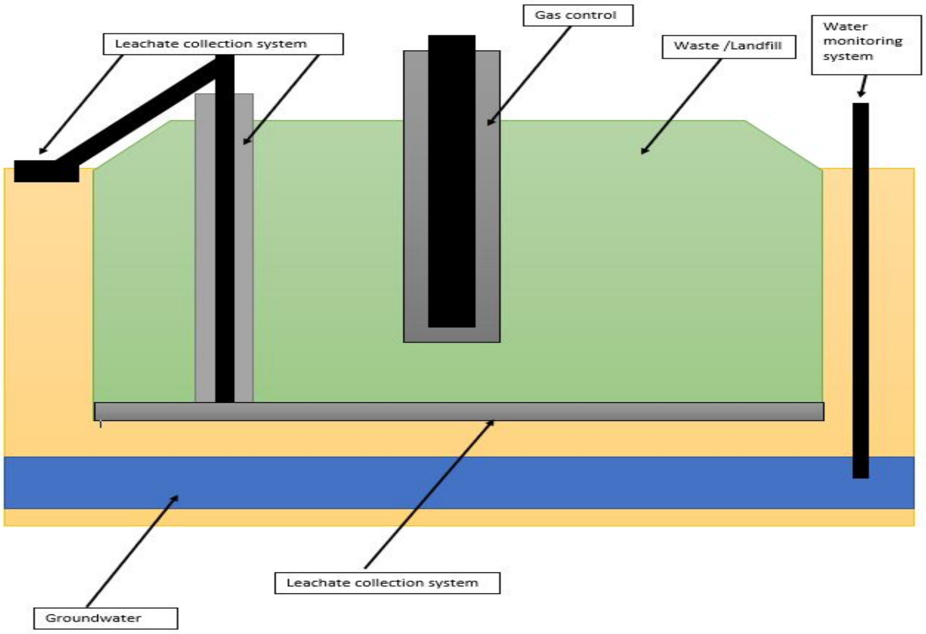

FIGURE 3- Gas collection system *(Dada&Mbohwa , 2017).*

Wang et al. demonstrated a **"pressure swing adsorption technology"** to purify methane from landfill gas and were able to concentrate methane by 90%. The collected gas can be used to generate energy ***(Wang et al., 2009).***

4.2 Anaerobic digestion

Anaerobic digestion is a process through which bacteria break down organic matter (such as animal manure, wastewater biosolids, and food wastes) in the absence of oxygen.

An interesting option for improving yields of anaerobic digestion of solid wastes is ***co-digestion***. That is, the use of a *co-substrate*, that in most cases improves the biogas yields due to **positive synergisms** established in the digestion medium and the supply of missing nutrients by the *co-substrates.*Co-digestion of manure and industrial organic wastes has been widespread in Denmark. Approximately 20 centralised co-digestion plants since the late 1980s, with very interesting results are present.**_(Mata_-Alvarez et al., 2000).**

In quite an interesting study of co-digestion, ***Hammes et al., (1999)*** considered the possibilities of treating **black water** (produced from recently developed vacuum/dry toilets) together with other types of human-generated solid wastes (biowastes/mixed wastes) in an **anaerobic reactor system** at thermophilic conditions. It was found that anaerobic digestion offers the possibility of integrating and simplifying domestic waste management while producing biogas and residues, which can either be used for agricultural purposes or be further treated through processes such as incineration ***(Hammes et al., 1999) (Mata-Alvarez et al., 2000).***

4.3 Composting

Composting process can be applicable for a wide variety of waste components like solid and liquid waste. Based on the products which are being composted, suitable ingredients are designed to enhance composting procedure ***(Misra et al., 2003) (Chaudhery et al. ,2022)***

Composting by nature is a random process, such as the breakdown of leaf litter or forest floor and the ageing of cow manure, but the period and natural composting modalities are lengthy and heterogeneous ***(Singh et al., 2011)***

4.4 Rapid fermentation test-

RFT is a technology that revolutionizes the traditional microbial composting, in which, with the use of patented **enzymes** and specialized equipment, organic wastes are stabilized and matured into ready-to-use high quality organic fertiliser within 3 hours, no need of composting or post-fermentation. The ability of some **hyper thermophilicbacteria**, e.g., the genera *Thermotoga*and *Pseudothermotoga*, to anaerobically ferment waste and formation of bioproducts has been really beneficial. These bacteria possess a set of **thermostable enzymes** to degrade complex sugars, with high production rates of biohydrogen gas and organic molecules such as acetate and lactate. Their high growth temperatures allow not only **lower contamination risks** but also **improve substrate solubilisation (Esercizio*et al., 2021).***

4.5 Immobilization of enzyme

Immobilization is a process in which enzymes are fixed to or within **solid supports**, creating a **heterogeneous immobilized enzyme system,** which mimic their natural mode in living cells. Study pointed out that all of these wastes are materials of great potentiality for enzyme immobilization even if coconut fibre is preferred. This result is of significant interest due to the low cost and great availability of such wastes, which actually are underused and cause significant environmental problems for improper storage ***(Anna Maria Girelliet al., 2020)***

4.6 Waste treatment by insects

Insect-Based Food Waste Treatment Methods is being increasingly recognized as an environmentally friendly method for recycling resources, and it also has the advantage of low installation costs. Additionally, such insects can be an excellent protein source through a certain procedure of extraction ***(Choi et al., 2017)(Hogsette & Farkas, 2000).***

Majorly used, the ***Black soldier flies***have an advantage over house flies is their behaviour. The black soldier flies tend to rest on vegetation and do not approach humans or animals. Moreover, their presence may contribute to biological control of the house fly by limiting house fly oviposition and reducing house fly larval numbers ***(Bradley &Sheppard, 1984) (Furman et al., 1959) (Sheppard et al., 1994).*** The ***Green bottle fly*** is a well-studied fly species and is an important ectoparasite of sheep, causing ***Myiasis*** known as '**Blow fly strike**' ***(Wall et al., 2001)***. The capability of larvae to remove necrotic tissue and promote healing has been utilized in the treatment of chronic wounds ***(Sherman, 2009).*** To exploit its medicinal properties, methods for aseptic and sterile breeding of both adults and larvae have been developed ***(Tachibana &Numata, 2001; Zhang et al., 2009)*** which minimize the risk of disease transmission. However, aside from its therapeutic applications, ***L. sericata*** larvae may be a useful tool in biodegradation of manure and waste from meat processing facilities.

Face fly larvae can feed on a variety of organic substrates, but are found most often in cattle manure. The larvae develop through 3 larval stages before migrating to the surrounding soil and duff for pupation ***(Arends &Wright, 1981) (Wang, 1964).***

Among the insects, food waste treatment using ***Black soldier fly (Hermetiaillucens) larvae (BSFL)*** is gaining significant attention ***(Lalander,2019)(Singh & Kumari, 2019).***

The larvae breakdown various organic wastes using their strong mouth parts and powerful digestive enzymes ***(Choet al., 2020)(Pastoret al., 2015)*** and effectively decompose organic wastes such as the debris of rotten animals and plants ***(Singh & Kumari 2019).***

Fly larvae have been traditionally employed to decompose poultry, dairy, beef, and pig manure ***(Eby & Dendy, 1978)(Miller et al., 1974)(Morgan & Eby, 1975)(Newton et al., 1977).*** Manure and faecal sludge are generally poor in nutrients, and the amount of biomass obtained by fly biodegradation is relatively low (generally 20–80 g/kg on a wet matter basis).However, recently fly larvae may be used even for biodegradation of other nutrient-rich wastes, such as food/restaurant waste, meat processing waste, abattoir waste, municipal garbage and market waste ***(Aniebo et al., 2008)(Diener et al., 2011)(Yehuda et al., 2011)(Zheng et al., 2012).*** Considering that many Asian countries, including those in southeast Asia, have high temperatures and humidity, industries related to BSF cultivation have high potential if implemented in such areas***.(Kim et al 2021)***

In China, as the population increases, the demand for milk and meat is gradually increasing, leading to an increase in livestock breeding. One study evaluated the conversion rate of organic matter as well as faecal soil performance during the composting of different livestock faeces using BSFL. Chicken, pig, and cow faeces were inoculated with BSFL and then composted for 9 days. Composting using BSFL reduced the organic matter and nitrogen by **20.3–22.2%** and **6.1–14.4%**, respectively, and accumulated VFAs(Volatile fatty acids) by **25.6–80.1%**. Thus, composting using BSFL is an effective method in developing countries such as China as it increases faeces maturity and the quality of the products obtained from composting ***[Liu et al., 2019).*** Bioconversion of waste with larvae may result in significant production of fly biomass and digested manure, which can be sold and thus create revenue ***(Wang et al., 2013).***

Protein extracted from the fly larvae and pupae compares favourably with soybean or animal meal commonly utilised in the feed formulations. Insects may also offer as a good dietary source of mineral salts ***(Khusro et al., 2012; Koo et al., 1980).*** Although fly larvae can accelerate the reduction of pathogenic organisms (***Escherichia coli and Salmonella sp***.) in manure and faeces ***(Lalander et al., 2013; Wang et al., 2013)***, several studies have shown that potentially harmful microorganisms may survive in both the larvae/ pupae and the processed waste ***(Lalander et al., 2013)(Yehuda et al., 2011).*** Thus live insects served as feed may act as vectors of bacterial and viral diseases ***(Khusro et al., 2012).***

Canadian company **EcoSpace Engineering Ltd**. perfected and patented a system for processing of organic waste (manure) by fly larvae, called **MILINATOR.**The biggest challenges currently facing the production of fly larvae from organic waste appear to be technological ones related to scaling up production capacity and producing large quantities of fly eggs, as well as a lack of knowledge regarding fly biology required for successful laboratory rearing. ***(Diener et al., 2011)(Eby & Dendy, 1978).***

4.7 Vermicomposting-

The most effective use of earthworms in organic waste management requires a detailed understanding of the biology of all potentially useful species ***(Edwards &Bohlen 1996).Perionyxexcavatus(Perr.)*** is an earthworm found commonly over a large area of tropical Asia ***(Stephenson, 1930)(Gates, 1972)*** although it has been transported to Europe and North America. This is an epigeic species which lives in organic wastes, and high moisture contents and adequate amounts of suitable organic material are required for populations to become fully established and for them to process organic wastes efficiently ***(Edward et al., 1998).***

4.8 Energy from waste-

Energy can be derived from waste that has been treated and pressed into **solid fuel**, waste that has been converted into **biogas or syngas**, or heat and steam from waste that has been **incinerated**. ***WTE technologies*** that produce fuels are referred to as ***waste-to-energy technologies***. The production of liquid biofuels like ethanol and biodiesel, syngas (hydrogen and carbon dioxide), biogas (methane and carbon dioxide), and pure hydrogen using advanced WTE technologies can all be utilised to generate energy. ***(The Cleantech Report. Waste to energy. Lux Research Inc.; 2007).***

According to ***Karimi K et al., (2006)*** rice straw is annually produced about 731 million tons which is distributed in Africa (20.9 million tons), Asia (667.6 million tons), Europe (3.9 million tons), America (37.2 million tons) and Oceania (1.7 million tons). This amount of rice straw can potentially produce 205 billion litres bioethanol per year, which is the largest amount from a single biomass feedstock.

4.9.1 Bio fuel from organic waste-

Biofuels can be classified based on their production technologies: ***First generation biofuels (FGBs); second generation biofuels (SGBs); third generation biofuels (TGBs); and fourth generation biofuels***. The FGBs are biofuels produced using standard technology from sugar, starch, vegetable oils, or animal fats, generally by seeds or grains. Examples include wheat, which produces starch that can be fermented into ***bioethanol***, or sunflower seeds, which can be pressed to produce vegetable oil that can be used to make ***biodiesel***. Second and third generation biofuels are also called advanced biofuels. SGBs made from non food crops, wheat straw, corn, wood, energy crop using advanced technology. ***Algae fuel, also called oilgae*** or third generation biofuel, is a biofuel from algae. Algae are low-input/high-yield feedstocks for making biofuels utilising more sophisticated technologies. They produce **30 times** more energy per acre than land. An emerging fourth generation, however, is based on the conversion of vegetable oil and biodiesel into ***bio gasoline***. ***(Demirbas, 2009).***

4.9.1.1 Biohydrogen

Currently, dark fermentation technologies are under the development at laboratory-scale to produce biohydrogen from wet biomass (e.g. molasses, organic wastes, sewage sludge) using ***anaerobic hydrogen fermenting bacteria***. Wastes and biomass rich in sugars and/or complex carbohydrates turn out to be the most suitable feedstocks for biohydrogen generation ***(Ntaikou, 2010).***

4.9.1.2 Biodiesel

Biodiesel production using BSFL was also studied in Malaysia. ***Fourier-transform infrared spectroscopy (FT-IR)*** was used to verify the successful conversion of lipids from 20-day-old BSFL growing on kitchen trash into biodiesel (***Ishak & Kamari, 2019***). It was also established that BSFL had the potential to be used in the manufacturing of biodiesel ***(Wonget al., 2018)***. BSFL had a 32% lipid content and 84% FAME(Fatty acid methyl esters) when esterified. Because the FAME level of BSFL is comparable to that of FAME produced from plants like coconut or palm oil, it was determined that producing biodiesel using BSFL could be a successful way to alleviate Malaysia's food shortages ***(Ishak& Kamari, 2019)***

4.9.1.3 Bio alcohol

Lignocellulosic biomass is visioned to provide a significant portion of the raw materials for bioethanol production in the medium and long-term due to its low cost and high availability (***Gnansounou et al.,2005).*** Bioethanol production from food crops is unmoral. Grain and other staple foods are essential because about 60% of people worldwide are currently undernourished ***(Pimentel et al., 2009).*** Producing bioethanol from lignocellulosic materials may allay many of the environmental and food-versus-fuel concerns that are drawbacks of producing bioethanol from food crops.

4.9.1.4 Bio oil

Lignocellulosic biomass can be converted into liquid fuels in three primary ways, i.e., synthesis gas production by **Gasification**, bio-oil production by **Pyrolysis** or liquefaction, **and Hydrolysis** of lignocellulosic biomass to produce sugar monomer units***(Qian, 2013).(Taherzadeh,2008)***

4.9.2 Other benefits-feedstock-

Although the body composition of ***Black Soldier Fly Larvae (BSFL)*** significantly differs depending on the substrate, the high protein content of BSFL make them a good nutrition source of animal feed ***(Kimet al., 2019).*** In fact, the crude protein content of BSFL after defatting was 60%***(Spranghers et al., 2017).***

4.10Microbial treatment of lignocellulosic waste

Lignocellulosic biomass is a plant material that is not used for food or feed. It mainly consists of agricultural residues, energy crops, forestry residues, and yard trimming ***(Rajesh Banuet al., 2021).***It is considered to be the third largest energy source after coal and petroleum products and one of the main sources of renewable carbon ***(Elsner, 2017).***Its worldwide availability, low cost, and low greenhouse gas emission make it one of the best options for the production of chemicals and fuel intermediates ***(Ojhaet al., 2021).***It was estimated that the annual production of lignocellulosic biomass on Earth is greater than 200 billion tons ***(Qian, 2013).*** It has a huge potential for the production of liquid biofuels ***(Kim et al., 2019).***

It consists mainly of ***cellulose (30–50 wt%), hemicellulose (20–40 wt%) and lignin (15–25 wt%)(Zhanget al., 2020)(Liang et al., 2021).***The remaining fraction of lignocellulosic biomass includes proteins, oils, and ash ***(Jerzak et al 2021) (Kapoor et al 2020).***

Microorganisms can also be used to treat the lignocelluloses and enhance enzymatic hydrolysis. The applied microorganisms usually degrade lignin and hemicellulose but very little part of cellulose, since cellulose is more resistance than the other parts of lignocelluloses to the biological attack. Several fungi have been used for this purpose. ***White-rot fungi*** are among the most effective microorganisms for biological pretreatment of lignocelluloses (***Sun& Cheng, 2002***).Some bacteria can also be used for biological pretreatment of lignocellulosic materials. ***Kurakake et al.*** studied the biological pretreatment of office paper with two bacterial strains, ***Sphingomonaspaucimobilis*** and ***Bacillus circulans,*** for enzymatic hydrolysis. ***(Kurakake et al., 2007).***

5. Challenges

- There is a huge gap between laboratory research and technological transfer to industry and commercialization. There is a need to establish joint efforts involving scientists, government, and industries.
- Developing countries, such as India and China, which produce a massive amounts of waste; this is expected to keep increasing because of continued population growth and industrialization need to focus on sustainable technologies.
- An increase in the efficiency of the waste to bioenergy conversion process is required and new, low-cost, controllable technologies that can provide the greatest amount of energy need to be created.
- An integrated approach needs to be implemented to provide major job opportunities .
- Effective process control mechanisms should be developed to prevent changes in microbial communities .
- People should educated to avoid mixing different wastes together because this impacts the processes and makes it more difficult and time-consuming to pretreat and separate distinct wastes. ***(Bhatia et al., 2018).***

6.Conclusion

Every potential for the reuse of waste materials must be considered in a world with dwindling resources and growing requirements. Since most human endeavour produces some garbage, opportunities abound. Animal, human, and agro-industrial wastes can all be used to assist the worlds need for food, fuel, and fertiliser. Research into both traditional and contemporary waste reuse techniques is prompted by rising petroleum prices, unbalanced foreign exchange markets, pollution, and soil erosion. The creation and application of waste reuse technology will necessitate an unusual level of coordinated effort from individuals and organisations with a diversity of capacities and skills. For waste utilisation initiatives to be effective, factors such as public health, the economy, institutions, and culture must be taken into consideration in addition to the technological components.

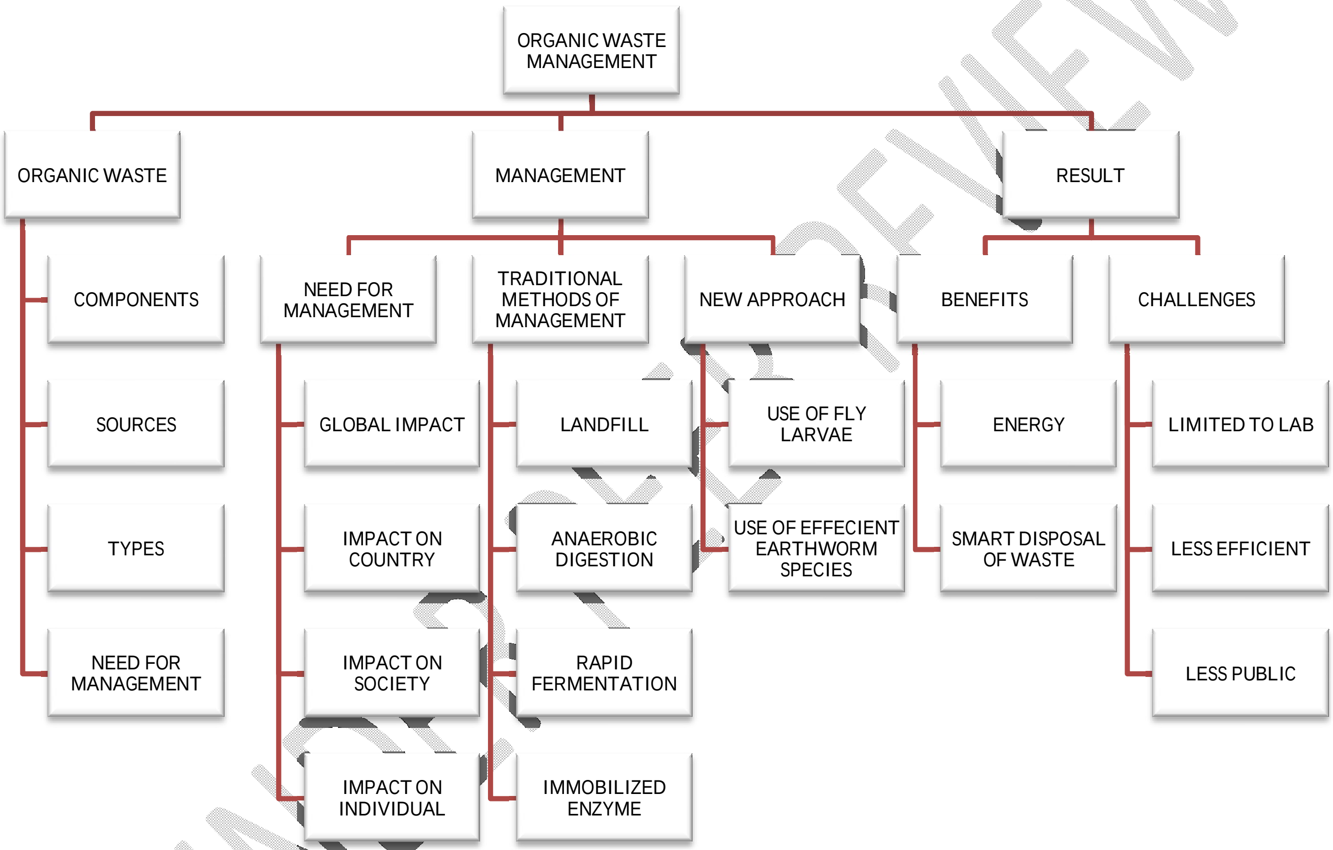

FIGURE 4- A summary of organic waste management.

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