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Review on the Suitability of Waste for Appropriate Waste-to Energy Technology

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Abstract

The use of garbage as a feedstock for resource harvesting is becoming more common once adequately treated. A process known as Waste to Energy (WtE) is used to make solid, liquid, or gaseous fuels from garbage. This fuel may be used to generate electricity and heat energy. Thermal treatment (incineration, gasification, pyrolysis, refuse-derived fuels) and biological therapy are the two main WtE treatment options (anaerobic digestion, composting). Due to its high organic content, municipal solid waste (MSW) is an ideal feedstock for WtE technology for resource harvesting.MSW has a wide range of characteristics. Separated food waste, green waste and paper and plastic trash are examples of MSW that may be broken down into mixed and separated categories. Moisture content, caloric value, carbon-to-nitrogen (C/N) ratio, particle size, and pH vary across various types of trash. The WtE technology has many features that may be used as parameters. The best performance of many technologies depends on trash with a particular property as a feedstock. This study aims to look at the characteristics of several MSW waste categories and suggest a match between these wastes and the currently-available waste-to-energy technology.

This means that mixed MSW is more suited for biological treatment. At the same time, separated MSW like food waste, which has a high concentration of volatile organic compounds, is more appropriate for combustion. The high calorific value and combustibility of plastic waste make it ideal for gasification and pyrolysis. In contrast, the presence of hemicellulose and cellulose in paper waste makes it a perfect candidate for pyrolysis.

Keywords: Solid waste management, Waste to Energy, Moisture, MSW process

1. Introduction:

Population growth will profoundly affect the environment, especially the creation of municipal solid waste (MSW). As the world's population grows, cities expand, and people's living standards rise, so will many MSW workers (Shahholy et al., 2008). Global MSW production now stands at over 1.3 million tonnes per year, and it is predicted that this figure will rise to around 2 million tonnes by 2025. This is in line with the rise in global energy use. Waste-to-energy (WtE) is a process that converts organic waste into fuels that may be used to generate power or heat (Lombardi et al., 2015). To reduce waste buildup and provide energy security, WtE technology offers a win-win solution.Standard WtE technologies include combustion, anaerobic digestion (without oxygen), pyrolysis, gasification, and composting. There are unique criteria for each WTE technology in terms of preferred waste displaying specific characteristics that meet the operational standard for an efficient process.

MSW may be fed straight into the incinerator, burning the garbage to produce energy. Pre-treatment of MSW to a maximum size of 350 mm will be required for other technologies, such as pyrolysis (Lombardi et al., 2015). For gasification, MSW must be reduced in size to avoid operational issues, such as a blockage in the gasification vessel, due to its large size. MSW is one of the most enticing feedstocks for WtE treatment. For the WtE treatment to be effective, MSW must have a high organic content, be readily biodegradable, increase moisture content, and have a reduced pH. The separated food waste, green waste and paper and plastic trash are examples of MSW that may be broken down into mixed and separated categories. The properties of various types of waste indicate which WtE treatment method is most suited for that kind of waste. Waste types suited for different sorts of proven WtE technologies are challenging to identify since MSW is heterogeneous and has a diverse composition. As a result, the purpose of this article is to assess the acceptability of waste types, depending on their properties, and to match these features with WtE operating settings.

2.0 Waste-to-Energy (WtE) Technology

It is possible to categories the WtE technology into two main categories: thermal and biological. Combustion, gasification, and pyrolysis are all examples of thermal treatment. Waste is fed at varying high temperatures and oxygen concentrations as part of these processes. In addition to generating energy, various byproducts and end-products are produced using multiple technologies.Composting and anaerobic digestion (AD) are examples of biological therapy. AD decomposes OM in the absence of oxygen, while composting decomposes OM in oxygen for natural decomposition. Biogas, which may be used to generate electricity, and a nutrient-rich digestate are the two end products of AD. It is possible to utilize the finished compost, which has the consistency of hummus, as a fertilizer or soil supplement. Composting generates a lot of heat because of the vigorous microbial operation.

The term "incineration" refers to the process of combusting and converting waste materials into heat and energy at a temperature of at least 850 degrees Celsius. This is the most widely utilized technique for waste to energy conversion. It is possible to find large-scale incinerators, such as the MWCs, MWIs, HWIs, boilers and industrial furnaces (BIFs), cement kilns (CK), and biomass combustor (BCs) on the market (Arena, 2011).

At a temperature between 200 and 300 C, gasification is defined as converting solid waste into fuels or synthesis gases (syngas) by adding an oxidant quantity more minor than that necessary for stoichiometric combustion. The power is burned to provide the required heat for the gasification process. Syngas is the byproduct of the gasification process and includes substantial amounts of partially oxidized compounds with a high calorific value. (Heerman et al., 2001). Commercially sound, syngas may synthesise natural gas, methane gas, methanol, dimethyl ether, and other chemicals.

Oil, gas, and char are the three primary byproducts essential to the production and refinery processes in many sectors (Arena et al., 2010). Because the process parameter may be adjusted to optimize product yield, pyrolysis demonstrates a high degree of adaptability. The created liquid oil may be used for various uses, such as boilers, furnaces, turbines, and diesel engines, all without the need for any further upgrades (Sharudin et al., 2015). On the other hand, pyrolytic products are more purified and more functional. There are three distinct pyrolytic modes, each with a specific temperature and processing or residence time.In the absence of oxygen, pyrolysis is a thermal process that breaks down lengthy chains of polymer molecules into shorter, simpler chains at temperatures more than 400 C (Lombardi et al., 2015).

Anaerobic digestion (AD) is a method in which microorganisms break down complex organic molecules into simpler ones, generating biogas in the process. Physical, chemical, and biological events occur sequentially and parallel in a complex process (Pontoni et al., 2015). Many organic wastes, such as municipal trash, food and industrial wastes, and sewage sludge, have been converted into energy sources through the application of AD (Bridgwater, 2012). Ad-produced biogas combines 60 per cent methane (CH_4) and 39 per cent carbon dioxide (CO_2), with trace amounts of water vapour, hydrogen, sulphur dioxide, and ammonia. Biogas may generate electricity (Yen and Brune, 2007). When this biogas is enhanced with 99 per cent methane, it may be utilized as a heat or energy source or converted into bio-methane (Chen et al., 2008).

Decomposition of organic matter such as manure, sludge, leaves, fruit peels and vegetables into an inert organic material by microorganisms in an aerobic environment is known as composting (or decomposition). A humus-like and nutrient-rich substance is produced by releasing carbon dioxide (CO_2) throughout the process. Instead of using chemical fertilizers, you may use compost, an all-purpose conditioner of the soil, to improve infiltration, minimize runoff, and save moisture.Because each WtE technology has its unique mechanism, the ideal waste stream for a given WtE system varies from one system to the next. As shown in Table 1, the operating parameters for various WtE technologies provide the appropriate requirements that trash should meet to maximize the WtE technology's efficiency.

Figure 1 Waste to useful energy using different techniques

3.0 Type of MSW and its Characteristic

MSW is a complex mixture of different materials, and its composition varies depending on the season and location. Many subcategories are available, each of which has unique properties that affect the WtE technology's effectiveness. Table 2 shows two types of garbage: mixed municipal solid waste (MSW) and separated MSW.

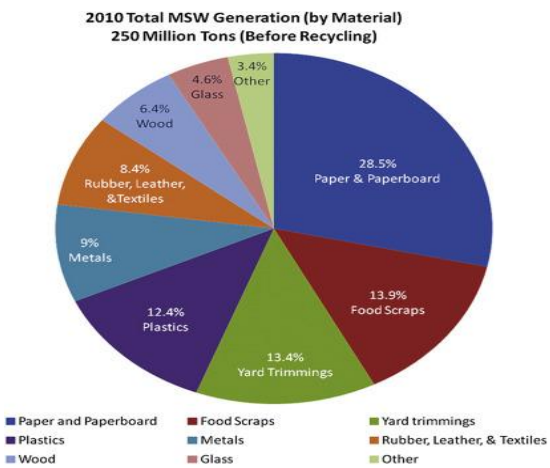

Figure 2Types of Wastes in 2010

Waste type	Moisture Content, %
Food Waste	50-70
Paper	4-6
Cardboard	5-7
Plastic	2-4
Textile	8-10
Rubber	2-4
Wood	20-25

Table 1 Waste Vs Moisture Content(%)

Many kinds of trash, including mixed and separated MSW instances. The non-segregated home garbage makes up the mixed MSW, while the food waste, garden waste, paper, and plastic are the main components of the segregated MSW. To properly feed WtE facilities with mixed MSW, it must be handled, separated, and provided in a controlled way (Marin et al., 2010). Vegetables, fruits, grains, and more are examples of food waste. The garden trash examples include leaves, grass, and twigs. Mill brock (paper trimming, paper scrap), pre-consumer (unused discarded paper), and post-consumer (used paper) are the three categories of paper waste (old magazines, newspaper). It's very uncommon for MSW to include plastic trash in four distinct forms: HDPE (plastic bags used for grocery shopping and garbage disposal), LDPE (light-density plastics such as grocery bags and food packaging), PP, and PS (e.g. food packaging, items packaging).The WtE technology's operating parameters must be matched to the waste characteristics to achieve effective and efficient performance, including heat recovery, resource recycling, cost-effectiveness, and time-saving benefits. Most municipal solid waste is a complicated combination of many materials, each with a unique set of properties. In general, they contain a lot of water and provide a lot of energy per area unit. MSW is classified as a mixed waste stream because it includes both organic and inorganic components in varying proportions.

Paper and plastics, for example, are separated both at the point of production and at the recycling facility. Because they cannot be used for energy recovery, glass and metals were omitted from the mix (Izumi et al., 2010).Depending on the waste type, the WtE technologies have varied physical and chemical features, which directly impact the WtE parameters.

A substance that can be securely handled, transported, and stored is the goal of preprocessing processes. Large inorganic items like metals and glass must be sorted out of the WtE process at the sorting stage. Shredding or grinding of waste was necessary for WtE technology to use as a feedstock. A drying procedure is necessary for trash with a high moisture level since thermal treatment requires waste with low moisture content. For example, mechanical-biological reactors (MBR) and refuse-derived fuels (RDF) serve as pretreatment examples (RDF). Composting and anaerobic digestion are two examples of biological waste treatment methods used in MBT facilities. MBTs are designed to handle the variety of trash generated by the average home.

Besides utilizing MSW as a feedstock, the production of RDF (refuse-derived fuels) via the preprocessing unit has become more common. Recycling and non-recycling materials are separated from one other during the processing of MSW, which involves shredding, size reduction, and pelletizing. RDF has a greater calorific value and a homogenous particle size, making it a valuable material.RDF fuels are mostly used in fixed bed reactors because of their low cost (Autret et al., 2007).

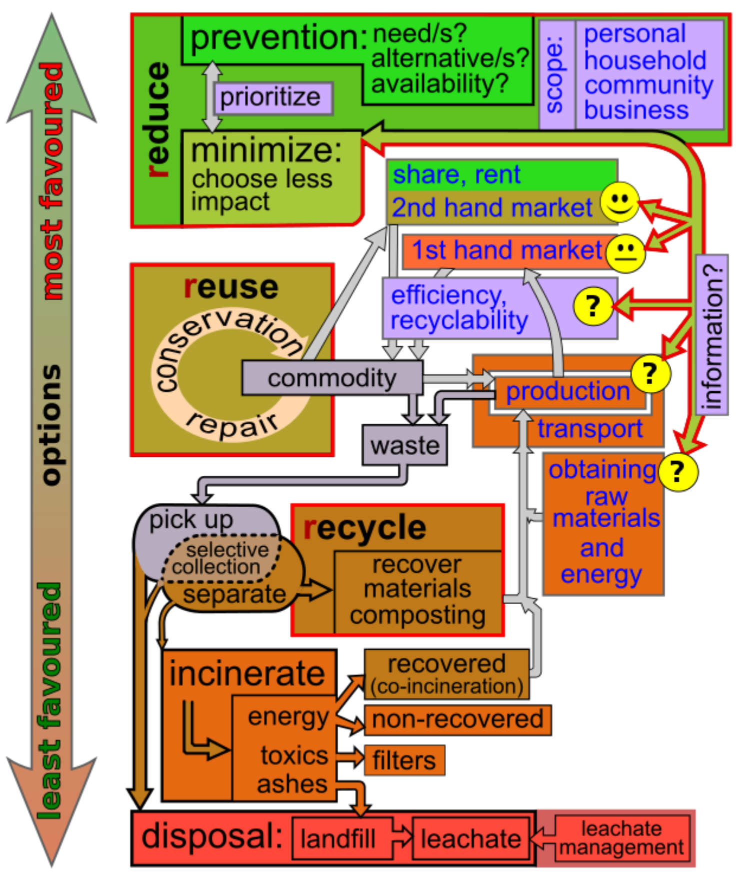

Figure 3Minimization of Waste

Characteristic/ Parameters	Conventional Combustion Mass Burn Incineration	Advance Thermal Treatment Gasification	Plasma gasification	Pyrolysis
Feedstock	MSW, biomass	MSW, biomass, black liquor, coal, hospital waste, sludge, tires	Hazardous waste, hospital waste, organic waste	Biomass, MSW coal, hospital waste, plastics, sludge, tires,
Suitability to unprocessed MSW with variable composition	Yes suitable but minimal waste pre-processing required and designed to process variable wastes	Pre-processing required & difficulties in accepting heterogeneous wastes	Pre-processing required & difficulties in accepting variable wastes	Pre-processing required & difficulties in accepting variables wastes
Commercially Proven System and Degree of reliability [45]	Proven & relatively simple operation than others. Scheduled/unscheduled downtime is as <10%.	More complex than combustion and less reliable. Scheduled and unscheduled downtime is as 20%.	Complex operation Scheduled and unscheduled downtime unknown	Not reliable data
Capital Cost	$775/annual design tone +/- 50%	$850/annual design tone +/- 40%	$1,300/annual design tone +/- 45%	Not reliable data
Operating Cost	$65/tone +/- 30%	$65/tone +/- 45%	$120/tone +/- 55%	Not reliable data
Residual to Disposal [46]	5% (by weight) if the bottom ash can be marketed for other applications.	<1 % if bottom ash can be marketed for other applications.	>1 to 10% varying due to the nature of the waste.	If treated, residues reduced to 0.1 to 0.3 tons per input tone.
Landfill capacity consumption	Reduced by 90 to 95%	Reduced by 90 to 95%	Reduced by up to 99% [46]	Reduced by up to 90%
Product	Electricity, heat (steam and/or hot water), recyc-metals, const: aggregate	Electricity, syngas, aggregate recovered from ash.	electricity, syngas, aggregate substitute	Electricity, syngas, pyrolysis oil
Energy recovery potential [46]	Ranges from 0.75 to 0.85 MWh/annual tone of MSW	Ranges from 0.4 to 0.8 MWh/annual tone of MSW	Ranges from 0.3 to 0.6 MWh/annual tone of MSW	Ranges from 0.5 to 0.8 MWh/annual tone of MSW [45]

Table 2: WtE Technology used in World Wide

Mixed MSW may be incinerated using a combustor, whereas pre-processing MSW can be used in a fluidized bed incinerator or rotary kiln. The Rotating kilns are usually utilized for hazardous trash, not mixed MSW. Anaerobic digestion is the best technique for food waste treatment because of its high moisture content, organic content and non-combustible components. Owing to the food waste's high moisture content and heterogeneous nature, heat treatment may be utilized, although with limited effectiveness due to the food waste's high moisture content. MSW also contains a significant amount of garden garbage. Composting is the best method for nutrient recovery since it produces compost that can be used as a biofertilizer or soil supplement. The thermal treatment may benefit from low-moisture, high-carbon feedstock such as fallen leaves or twigs, but the burning process might be a nuisance to the public. Burning, gasification, and pyrolysis are all viable options for plastic trash disposal. Due to the high polymer content in plastic trash, incineration is not the best option for plastic waste treatment. Instead, gasification and pyrolysis are preferable options. The thermal treatment may be used for paper waste, which accounts for most flammable material in MSW. In terms of operating temperature, pyrolysis is more versatile than gasification in utilizing paper waste as a source of renewable energy.Based on the nature of the feedstock, WtE technologies may perform very well (waste). The characteristics of the waste utilized impact the performance of WtE technologies, their applications, and their outputs. Trash to Energy (WtE) systems may handle all sorts of waste if they are properly pre-processed; however, this may be prohibitively expensive and impractical for the technology's performance.

The environmental benefits of recycling recyclables like paper and glass can't be overstated, even if they don't come within the WtE umbrella. Material flow analysis (MFA) and life cycle assessment, according to Sevigné-Itoiz et al. (2015), showed a decrease in GHG emissions of 36-317 kg CO_2/t waste paper collected (LCA).It was shown that when biomass was not used as a feedstock in a pulp and paper plant, CO_2 emissions were reduced by 1,100 kg CO_2/t when the recycled paper was used (Laurijssen et al., 2010).

4.0 Conclusion:

Depending on the waste (MSW), WtE methods and production yields might be significantly affected. Low moisture content and high calorific value are necessary for optimal thermal treatment results. Organic waste with high moisture content, such as food and garden waste, is most suited for biological treatment. Waste is a critical aspect of WtE performance and implementation. Because of the differences in climate and geography, waste may have a variety of distinct compositions and properties. This location's waste composition needs to be assessed before an appropriate WtE technology can be selected.

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