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Strategies used to treat waste material for energy production on sustainable basis

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Abstract
In the developing world, traditional forms of energy are rapidly eradicated, and contribute freely to global concerns such as waste exposure and dangerous deviations in an environment. So, it is required to develop and used renewable or humorous energy resources for future. Every month, a huge amount of waste is generated and becomes the part of landfill or sent to less developed areas, and sometimes left untreated. It has significant environmental consequences for biological systems, and human well-being. Due to this, numerous new waste disposal plants have emerged and developed to generate energy from garbage dumps. Large amount of trash created each day for landfills causes numerous critical ecological effects. Various new approaches are accessible for changing waste materials into energy sources, going from exceptionally straightforward frameworks of discarding waste to more perplexing advancements fit. Waste can be converted into energy by using three possible strategies such as thermochemical, biochemical, and chemical changes. This article explores the impact of waste on environment, and how waste can be used to generate energy.

Introduction

Waste material is an unavoidable evolution of the world and is a burning question to manage huge volumes of waste. Various approaches has been developed to reduce the production of waste materials and to reuse the waste materials [1]. However, the massive part of waste materials still needs to be process effectively. The waste management departments are unable to solve the issue. So, the energy sector also contribute to solve the issue and use the waste materials for fulfill growing energy demands [2]. Squander is an unwanted material of society however is a significant energy source. In energy production from waste may resolve the difficulty of handling the waste materials and also to generate energy [3]. The relationship between the dumping of waste materials and production of energy differs drastically. Various nations decide to approve the systems based on public, economic, and conservational models and limitations. The mentioned models affect the energy security, energy value, and waste management [4]. The production of energy from waste materials leads to climate-friendly energy production, and waste management [5]. There are numerous types of waste materials based on their source.

Municipal Waste

N matter, including sewage, manure, mechanical or business waste, and the combination of matter such as inorganic trash from any openly or secretly worked systems or from any waste streams is a municipal waste [6]. The remarkable development of the total populace, the urbanization, the financial turn of events, and the improvement of expectations for comforts have prepared an incredible increase in waste materials [7]. The amount of waste materials has expanded over the years in agricultural nations, and their administration faces numerous challenges for disposal [8]. The natural biodegradation of municipal waste generates biogases leads to air contamination. Atmospheric deviations including methane and hydrogen are exceptionally combustible and are not environmental friendly [9].

Demolition and construction waste

Remodeling and destruction of building structures and exercises produce numerous substances known as wastes of development and destruction [10]. The type of development and destruction waste changes according to the place such as the development of roads creates uncovered materials, while the destruction of buildings creates a consistent type of waste [11]. Based on their composite character, they are isolated into two classifications as inactive materials (such as concrete and blocks) and non-inactive materials (such as rebar and wood) [12]. The waste materials are described on the basis of their volume and weight and expensive coordination is required for disposal [13].

Industrial waste

Industries produce waste materials of different series including inorganic waste material, kiln debris, slag, and tiles. Most modern waste comes from three types of companies such as metallurgical, non-metallurgical, and diet processing companies [14]. Waste can vary from one sector to another depending on utilized raw materials, production activities, and the points of sale. This type of waste can be classified into 3 structures as solid, liquid, and gas [15]. The inorganic fractions, natural components, biodegradable, non-biodegradable components, and recyclable materials are also included. Liquid industrial waste materials are natural and inorganic components that are soluble or acidic, decomposable, suspended, and inseparable [16].

Medical waste

Clinical waste or medical care squander is the fluid waste produced from medical places [17]includes a wide-ranging of materials of needle inspection, blood holders, swabs, histopathological assortments, tissues, waste samples, razors, surgical blades, other care devices, and radioactive materials [18]. Normally, the source of medical waste materials is the patient diagnosis materials, medications, or vaccinations of people. This type of waste can be classified into hazardous (irresistible, harmful, and radioactive) and non-hazardous divisions [19]. Waste of medical care undermines the biological system leads to mutations. Moreover, the poor management of clinical waste leads to serious health risks [20].

Toxic Waste

Toxic waste materials can cause an extreme danger to individuals and the climate. These can be explosive, oxidizing, harmful, irresistible, combustible, corrosive, and radioactive substances [21]. Toxic material are inflammable, poisonousness, destructiveness, and reactive [22]. Oil processing plants, plastic, fiber producers, paper and mash companies, tanneries, cowhide, and metallurgy companies are the main source of unsafe waste materials [23]. Colors, dyes, stains, engineered saps, naphthalene intermediates, petrochemical squanders, polyethanolamines, phthalates, nitro organic synthetic substances, agrochemicals, pesticides, acrylates, and pharma compound squanders are also included in dangerous synthetic compounds [24]. These waste materials directly effects the populations by different sorts of substances which cause ulcerations, silicosis, neurotic signs, bacillus anthracis, harmful frailty, jaundice, dermatitis, asbestosis, malignant development, susceptible responses, pneumoconiosis, and nephritis [25].

Agricultural waste

Farming wastes are commonly high in supplements (phosphorus and nitrogen), biodegradable organic carbon, pesticides, and fecal coliform bacteria (microscopic organisms that typically live in the digestive system of warm-blooded animals). Nitrogen as alkali (NH_3) and nitrate subordinates (- NO_3^-) can lead to eutrophication [26]. Nitrogen (nitrogen gas) is harmful for plants while decomposition of dead aquatic plants and blue-green growth can transform nitrogen into alkali and nitrate. This association highlights the complexity of aquatic environment [27]. Favorable approaches need to overcome the agricultural waste materials. The significant approach is to stop contamination for the prevention of human sewage, cows' fecal matter, and fertilizers dumped into streams. Feedlot seepage also has high potential for water pollution. Aquaculture is also sensitive to waste materials [28]. Interestingly, low weighted squanders can debase the water quality depends on the stomp of water framework bank. However, the compost holding lakes can permit to flood leads to debase the water quality of adjacent streams [29]. Both surface and groundwater pollution are normal in farming districts due to the breadth of manure and pesticide application (**Table 1**).

Impacts of Waste Material on Environment

The waste materials have been injurious to the environment. A gigantic amount of waste materials has been produced and difficult to handle. Non-biodegradable and reusable waste materials are dumping in oceans and landfills [30]. Overall, the quantity of waste produced disturbs the climate manifold and it has negative consequences on the living and normal habitats [31].

Climate Change

Disposal of waste materials is a matter of concern. In this decade, garbage disposal has become even more careless, and involved in climate change [32]. Methane gas is released and discarded in the landfill. Open landfills have 91% methane emissions. The consumption of fossil fuels is releasing carbon dioxide leads to global warming. The ozone-depleting substance emits dangerous amounts of carbon dioxide due to the consumption of heavy waste and open garbage in various parts of the world [33]. Analysts have concluded that nearly 40 percent of waste of the world is incinerated, which affectation a great threat to the environment [34].

Wildlife

Weather usually varies from region to region however the excessive waste materials are very dangerous for forests, oceanic lives, and other wild lives [35]. Waste materials also disturb the wildlife of sea animals. These wildlife organisms usually cannot differentiate between the food and waste materials, and utilize the waste materials as food leads to toxic effects [36]. Waste materials are continuously damaging the life of sea animals including fish, seals, turtles, whales, and many other marine animals. Researchers have also discovered several classes of over 1,000 species of plastic which are affecting the wildlife severely. Some plastics contain microorganisms like bacteria, viruses, and protozoa [37]. These organisms act as a vector for transmitting the disease into wildlife. The concentrated micro plastics are discharged Bisphenol A and phthalates which can destroy the hormonal system of wildlife animals. From a biodiversity perspective, the waste problem seriously undermines the power of species in the world [38].

Public Well-being

Public welfare is at stake due to poor waste management. The huge amount of waste materials it is destroying the environment and natural life in the biological systems [39]. The production of waste materials is directly proportional to damage the lives of organisms [40].

The waste materials also enhancing the diseases including Asthma, malignant growths, heart disease,

Table 1: Sources and types of waste materials

Source	Type	Composition
Municipal waste	Domestic	Nutrition lavishes, e-wastes, paper, plastics, ingredients, firewood, glass, metals, unique squanders (for example, bulky things, buyer hardware, batteries, oil, tires), family hazardous squanders
	Municipal facilities	tree trimmings, the landscape, street sweepings, sludge, and wastes from recreational places
	Industrialized	Housekeeping squanders, bundling, food squanders, wood, steel, concrete, blocks, remains
	Marketable & organized	Paper, cardboard, plastics, wood, food squanders, glass, metals, and e-squanders
	Destruction and structure	Forests, harmful waste, solid, plastics, blocks, slates, cut-glass, dust, lagging, and metallic
Course wastes		Topsoil, off specification products, Clash constituent's dirt, unwanted coalfaces, and harmful substances
Medical wastes		Contagious wastes, dangerous debris, radioactive substances, harmful garbage, pharmacological waste
Agricultural disposal		Rice shells, animal waste, fiber debris, coconut shells, rotted food wastes, dirty water, silage waste, plastic, clash machines, bug juice, livestock medications

adolescence, COPD, irreversible infections, low birth weight, and premature birth. The waste materials also enhancing the diseases including Asthma, malignant growths, heart disease, adolescence, COPD, irreversible infections, low birth weight, and premature birth. In waste materials including bacteria, insects, and worms also affect the human health [41, 42].

Technologies

The transition of energy through the waste materials can be achieved by using various innovations (**Fig. 1**). Waste energy strategies have obvious features and are largely possible, depending on several limitations. The components present in waste materials and their composition help to generate thermodynamic energy. There are three major types of strategies are used to produce energy from waste materials [5].

Thermochemical Conversion

It is a transformation strategy to restore the energy from waste materials using a higher degree of temperature including inflammation, gasification, and pyrolysis. The use of high temperature and air within the cycle differentiate this approach from others. This translates the waste material into valuable items. Dry waste is a very suitable raw material for promoting thermochemical changes.

Combustion

Waste combustion is the complete oxidation of flammable substances contained in waste material, and the reaction is very exothermic. Complex cycles occur during the intense incineration of the waste materials [43]. Initially, the heat in the combustion chamber destroys the moisture present in the waste material and destabilizes the components of the heavy waste. After the ignition, air is used to initiate the actual combustion reaction, and subsequent gases come into contact. Reaction is the conversion of residual fuel into gas, heat, and ash [44]. It is used to generate the high-pressure overheated steam from the emitted hot water, followed by a steam turbine connected to a generator for electricity. Inorganic bases and fly residues are composed of waste and are not particularly involved in the incineration process, however they affect the energy balance due to the average heat range [45]. Depending on the basic waste treatment options, iron and non-ferrous metals can also be recovered [46].

Gasification

The strong gasification of waste materials is partial oxidation of waste material in the existence of less oxidizer [47]. The gasification converts strong or carbon-based waste into valuable side products, including valuable oxidation mixtures such as carbon monoxide, hydrogen, and carbon dioxide. Additionally, partial incineration, or heat energy is used through outward heat source for the process of gasification [48]. A gas called syngas is produced in this process, which is used for various purposes. After refinement of Syngas gas, it can be used for high-energy synthetic materials or gasoline [49]. It is also used in more efficient gas turbines and internal ignition motors or used in traditional burners connected to heaters and steam turbines [45].

Pyrolysis

The pyrolysis of solid municipal waste is decomposed at a high temperature in the absence of air around 500ºC and 800ºC, and changes the thermal waste materials into gas (synthetic gas), liquid (bitumen) and solid [1]. The main purpose of pyrolysis is to increase the strong decomposition of waste materials and convert it into gas and high-density phases. The concentration of pyrolysis products (CO, H_2 CH_4, and various hydrocarbons) and their value are depends on pyrolysis temperature and heating rate (**Table 2**) [50]. The mechanical treatment before gasification has significant impact on raw material, a low calorific value of fuel, an expensive cleaning structure of ventilation gas [50].

Biochemical conversion

In biological transformation, the waste material is changed to valuable products using a microbial cycle and is limited to biodegradable waste, such as food and garden waste. Similarly, moist materials and local waste materials (biogenic sector) are the most preferred raw materials for biochemical conversion.

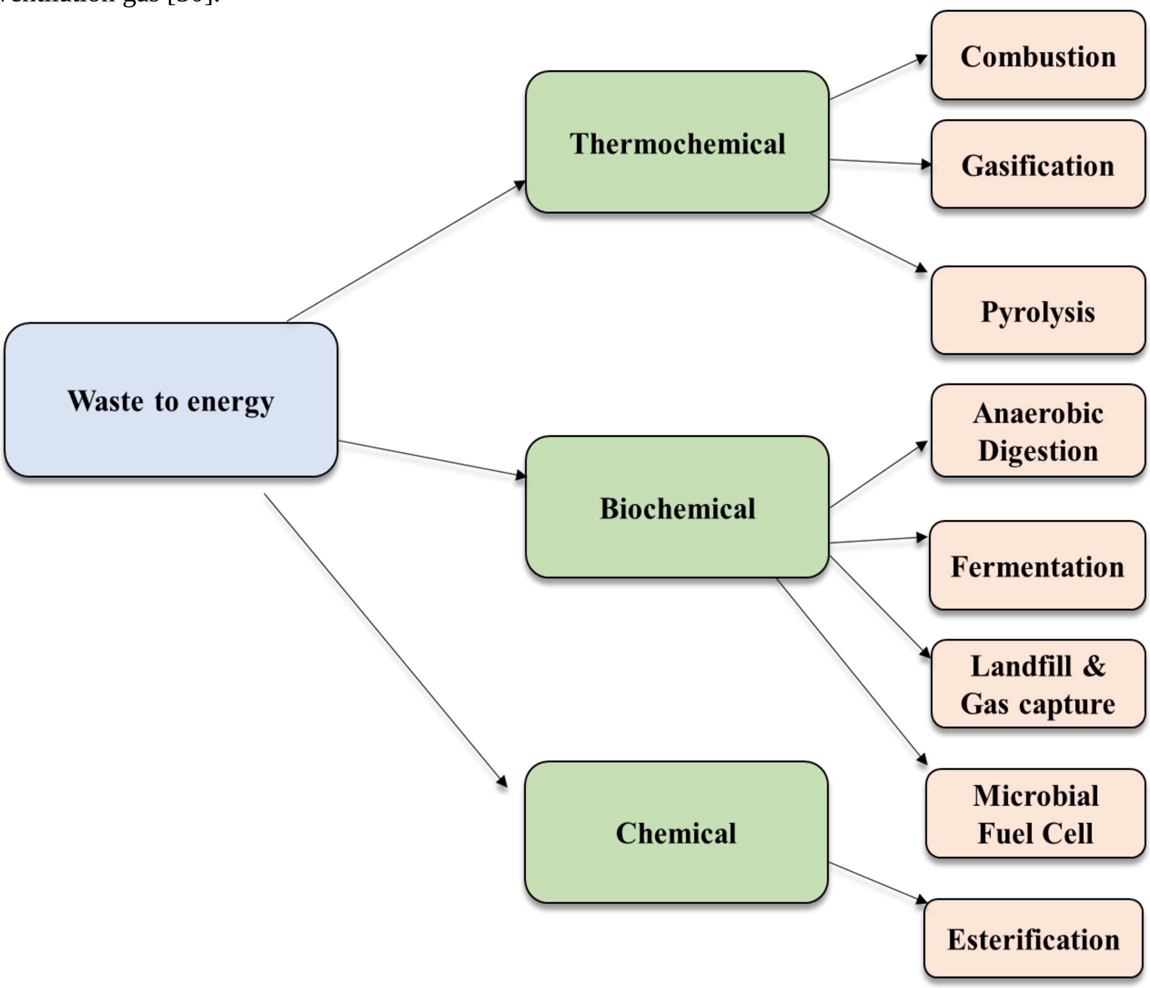

Figure 1: Types of waste to energy production technologies

Table 2: Combustion, gasification and pyrolysis

Combustion	Gasification	Pyrolysis
Generally, air is not present	Substitute stoichiometric air, Endothermic/Exo-thermic	Surplus air Highly exo-thermic
Single heat	Lower full volumetric flow	Greater volume flow rate
Gases not wanted only liquid want	Lesser fly slag carries over	Maximum fly slag carries over
The reduced forms of pollutants (COS, H2S)	The reduced forms of pollutants (COS, H2S)	The reduced forms of pollutants (NOx, SOx, and the so forth)
Greater char	Char at a small amount of temperature	Lower ash
Extra O_2 is not present	Some amount of extra oxygen is present	Much extra oxygen (or air)

Anaerobic digestion (AD)

Anaerobic digestion is a cycle to degrade natural substances by anoxic microorganisms. The supply of biogas and gas containing methane used as fuel [51]. The working time per cycle is 15-30 days. The biogas is used as an integrated unit of heat and electricity (CHP) to generate environment-friendly energy such as electricity and heat [52]. It is also participated in the production of biofertilizers, and biofertilizers are treated as pathogen free and can be applied to agricultural land twice a year, effectively replacing fertilizers from non-renewable energy sources [53]. There are different types of AD frameworks

Mesophilic or thermophilic

The past cycle operates at a temperature of 25-45° C, while the later cycle requires a higher temperature of 50-60° C. The thermophilic structure produces a powerful raw material for cleaning the harmful pathogens and faster production of biogas for each unit of the feedstock. The structures require more cost and more management than mesophilic bacteria [54].

Wet or dry

Wet and dry refers to anaerobic digestion of raw materials. In wet, AD is 5-15% is a dry matter, and can be sifted and mixed. In dry, anaerobic digestion is >15% dry matter, and it can be stacked [55]. Dry AD generally works cheaply as has less heat water and produce more gas per unit from raw materials. In contrast, wet structures usually have a lower cost of capital for installation, and dry structures are generally compatible with municipal solid waste treatments [56].

Continuous flow or batch flow

Maximum AD plants work on continuous growth of raw materials because of low-cost and supply has more biogas as per input unit. It is difficult to restart the structure from the cold and to open the digester regularly. However, dry structure works with an ice stream, and a multi-group digester that changes temporarily over time [57].

Single or multiple digesters

Anaerobic digestion occurs at various stages, and wet frameworks may require different processors to ensure effective productivity. Various digestion tanks have a higher cost of capital and labor costs, require more control, and can supply more biogas per unit from raw materials [58].

A Vertical tank or horizontal plug flow

The vertical tank has raw materials on one side and digestate control on the other side. If there are stronger ingredients, A horizontal plug flow is selected for stronger ingredients [54]. The final form of a vertical tank is exclusive to manufacture and operate, however, the feedstock stream speed can be exceptionally controlled in the digester [59].
The selection of anaerobic digestion strategy will be depended on various elements such as, raw materials, single digestion or co-digestion, space, wanted productivity.

Fermentation

Fermentation is the processing of natural waste materials and its conversion to alcohol or acid (ethanol, lactic acid, and hydrogen) in the non-availability of oxygen. Fermentation is involved in the production of bioethanol, which is important in the automotive sector [60]. Batch and continuous fermentation processing are used to carry out yeast fermentation, while batch fermentation gain preference on continuous fermentation due to less contamination [61]. The plants help in the production of bioethanol and produce about 200000 to 300000 tons of ethanol annually. In the West, bioethanol is mainly made from soft substrates such as wheat, corn and barley [62]. The successful use of lignocellulose biomass as a substrate also gain priority [63]. It is still predictably expensive as cellulosic substrates require pre-treatment with acidic, heating, and enzymatic treatments. Test efforts to extend the catalytic activity of an enzyme and reduce chemical costs to allow financially justified broad-spectrum protein applications. Acidic, solvent, and alkaline treatments are in ongoing cycles to break down the biomass created to increase ethanol yield and reduce the energy demand [64].
Silage left over after refining of alcoholic fermentation by-products is commonly used to make

livestock feeding [65]. The difference between anaerobic digestion and fermentation is given in (**Table 3**).

Landfill with Gas capture

Landfills are an important source of ozone-depleting material flow, and methane is mined to use as an energy source. Natural substances that decompose in landfills usually produce a gas consisting of half methane and half carbon dioxide known as landfill gas (LFG) [66]. Methane is a powerful substance that breaks down ozone and has much more potential for climate change in comparison with CO_2. The extraction of methane emissions from landfills is beneficial not only to the climate, but also to the energy sector [67]. Biogas is directly used in boilers, furnaces (concrete, stone tools, blocks), microphone dryers, infrared coolers, leachate vaporization and blacksmithing furnaces [68]. Biogas primarily used in heating cycles which produce biofuels such as biodiesel and ethanol and also for alternative energy sources including bottled petroleum gas, flue gas condensation and methanol. The tasks that utilize cogeneration combined heat and power (CHP) to generate electricity and recover heat energy are more efficient [69]. The most common way to capture biogas is to cover the landfills and include collection structures with horizontal or vertical channels. Both gas collection structures are enforced for configuration decisions depends on specific site and the installation time [70]. They can also use mutually, such as the utilization of a horizontal collector and a vertical well. As the gas passes through the collection structure, a certain amount must be collected and processed [71]. The gas is drawn from the collection well into the collection head followed to pretreatment along with the blower. Large amount of gas explode in open or enclosed conditions during startup and down time of energy recovery structures, controlling biogas emission, and conversion limits are exceeded [72]. Treatment of water, cells and various pollutants is fundamental, through the type and grade used depends on the type and specific properties of the energy recovery site. The minor treatments can be used for boilers and most internal combustion structures, although other gas turbines, micro turbines along with more sophisticated technologies are used to remove materials such as siloxane and hydrogen sulfide through composite floors, and organic scrubbers [73].

Microbial fuel cell (MFC)

MFCs are biochemical-catalytic structures used to oxidize the biodegradable natural materials in the presence of enzymes or bacteria [74]. Bacteria must be used in MFCs for the power generation, as well as biodegradation of natural matter and waste [75]. The major waste materials for microorganisms include marine debris, soil, sewage, freshwater residue, and active secretion. MFC separated the anode chamber and the cathode chamber by a proton exchange membrane [76]. The anodic component is usually maintained without oxygen however the cathode either appears in the air or is immersed in some aerobic environment. Electrons typically flow from anode to cathode through an external circuit with a resistor, battery, or other electrical device to hold the charge [77]. The action of MFC involves organisms that oxidize the substrate in anode orbit, produce CO_2, and constantly produce electrons and protons. The electrons are consumed from anode towards cathode. At the intersection of the proton exchange layers, protons enter in the Catholic chamber, where they combine with oxygen to form water [78]. In this process, the substrate splits into CO_2 and water, with the production of energy. This innovation is suitable for the areas where the range of electricity production is limited [79]. MFC is used as a sensor device to test the levels of erosion and pressure coefficients in deep-ocean gas and oil pipelines. Applications apply to bio hydrogen preparation, water treatment (odor extraction, desalination, sulfide removal), biosensors (as sensors for toxicology testing and cycle research), and bioremediation [80]. This innovation is still in its beginning and is associated with functional issues such as little density and power. However, usually cell cannot generate a certain amount of capacity in the sensor or transmitter [81]. The era of lightning by eliminating the proton exchanging membrane and creating an intracellular barrier, such as a single cell, the stack and upstream MFC [82]. MFC also does not work at low temperatures because microbial reactions are delayed at low temperatures. The commercial use of this harmless waste to energy invention for ecosystems is not yet practical due to the lack of forming capacity for the production of reactor cathodes and the considerable cost of the conductor material [83]. The microbial fuel cell has been shown in **Fig. 2**.

Table 3: The difference between anaerobic digestion and fermentation

Anaerobic Digestion	Fermentation
The opening stage is hydrolysis	The opening stage is hydrolysis
The last step is a methanogensis	The last step is a distillation
The most important output product is the biogas	The most important output product is alcohol
Currently used globally for dealing of waste as well as an additional type of feedstocks	Currently, some services are existing for the treatment of globally waste; facilities using other feed stocks do

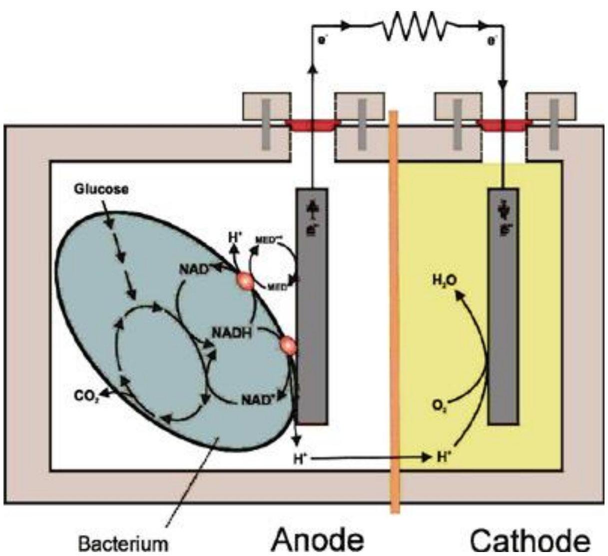

Fig. 2: Microbial Fuel Cell (Source:[76])

Chemical conversion

Esterification

In esterification include the reaction of fats and alcohols, and an alkali NaOH used as a catalyst. A glycerin with the three long chain fatty acid is a base of a triglyceride molecule [84]. Alcohols react with unsaturated fats to form unrefined glycerol with mono alkyl esters or biodiesels used in catering, pharmaceutical, food and dyeing industries. The use of alcohol is methanol and ethanol and the product will be methyl esters or ethyl esters respectively [85]. Suitable bases for methyl esters are potassium hydroxide or sodium hydroxide, and for ethyl esters the latter bases are more suitable. Esterification is affected through the chemical structure of an alcohol [86]. Biodiesel is used for transportation and can be distributed from fats and oils in three ways as basic contact transesterification of oil; transesterification of oil with a direct acid catalyst; convert oils to unsaturated fats leads to biodiesel. The most efficient process is basic catalytic transesterification for supplying biodiesel [87].

Arising Technologies

Hydrothermal Carbonization (HTC)

It is a chemical acceleration of normal geothermal cycles using acid as a catalyst. It looks like an extraordinary production cycle that uses a mixture of heat and pressure to artificially convert bio-waste into a carbon material with properties [88]. A misty waste is heated in a pressure cooker at a moderately low temperature of about 200° C over a period of 4 to 24 hours. Feedstock is converted into coal for carbon sequestration [89].
Pre-preparation is required before feedstock carbonization and glass metal must be removed. An input test material should have great humidity (> 70 percent) than other hot treatment feedstocks. There is a need of catalyst as acid. Any natural material including lignocellulosic material, can be coalified to keep food waste moist enough [3].
This method releases the lowermost quantity of greenhouse gases of every bio-waste to fuel transformation procedure and a by-product is toxin free water.

Hydrothermal Carbonization

Hydrothermal Carbonization is an extremely well-organized and environmentally supportable process of changing bio-waste into fuel.
The various advantages of this invention are versatility, fast and stable operation, an odorless and quiet operation, market access to the goods company, attractive speculation for private financial backers, thereby decreasing community debts.

Dendro Liquid Energy (DLE)

DLE is a new German breakthrough technology for the treatment of biological waste, and have potential in the area of waste to energy production [46]. DLE plant reactors can treat a variety of wastes, from plastics to tree stumps, and provide refined fuels such as carbon monoxide and hydrogen in the age of electricity. As compare to anaerobic treatment of waste, DLE helps to produce more anaerobic digestion or interruption on the plant site. Dendro liquid energy gives 4 to 8 percent inert debris to landfills [90].

Applications

Electricity

The direct ignition is used to produce heat from a waste material, and this dissipated heat is used to generate steam to give power to the turbines. The productivity levels during indirect generation range from 15% to 27% [91]. The electrical efficiency of combustion is generally higher than gasification due to its low operating temperature and steam suppression factor. Pyrolysis and gasification produce flammable engineering gas (Syngas). It can be used to generate electricity and it can be refined and used directly in gas turbines and engines [92]. Gas turbines or motors accept more remarkable capacity from direct ignition than steam turbines.

Heat

The traditional process to produce heat energy from waste material is through ignition or syngas consume to generate steam by a boiler framework [93]. The conversion of syngas into methane may use in gas industry. This technology is even extra operational because heat is delivered into great-capacity heaters [94].

Combined Heat and Power (CHP)

Waste to energy plants can supply heat and power with power generation units (CHP) to increase the overall productivity up to 40%. The heat produced through power generation is seized and used [95]. Persistent demand for the heat can provide maximum economic benefits depending on the area and heat transfer capacity of the plant.

Transport Fuels

The waste to energy cycles also produces the energy that can be used by transport vehicles. The syngas can be burned in an engine to convert into biomethane developed by gasification and pyrolysis [96]. Syngas can also be used to produce diesel and jet fuels. Oil can be produced by pyrolysis and requires additional treatment to convert diesel and petroleum [97].

Conclusion

Waste power plants give two significant benefits as waste disposal and energy production. Three types of energy production technologies are chemical, biochemical and thermochemical, to produce stable stainless energy. By improving energy producing strategies from waste, the problem of waste disposal can be eradicated. The toxic waste materials can also be reduced which cause serious health issues, global warming, ozone layer depletion. It produces electricity for the power plants using petroleum products as an energy source. Biodiesel and bioethanol can also be produced by these strategies. In conclusion, the use of waste to energy production with different technologies and these strategies can be helpful for mankind to reduce the waste materials. The waste material can be used in a suitable way to produce enough energy for consumption.

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Conflict of interest

The authors declare no conflict of interest.

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