Chapter 5
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Promising Recovery Directions for Waste Plastic as an Energy Source: A Brief Overview

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ABSTRACT

This study aims to provide a summary for recovering energy from waste plastics, which might be used as an alternative energy source in the near future. Energy security and the transition to a thriving low-carbon economy are critical for a growing nation like India. By mixing locally produced ethanol with gasoline, India may be able to improve its energy security, encourage small enterprises and farmers to enter the energy industry and reduce emissions. However, the widespread usage of plastic items poses significant disposal challenges and worries about the environment. Some researchers believe that waste plastic fuel created by pyrolysis may be used to replace fossil fuels. The disposal of waste plastic has the potential to save and recover a significant amount of energy. The chemical characteristics of waste plastic fuel vary depending on the plastic grade and the pyrolysis process used to produce it. Energy recovery options from waste plastics are discussed and summarized.

Keywords: Waste plastics; energy recovery; pyrolysis; recycling.

1. INTRODUCTION

When it comes to decay, plastic materials might take hundreds of years to decay. The decay process takes longer than usual because the chemical bond is mainly composed of carbon and hydrogen. The disposal of synthetic materials causes stress on the soil ecology via landfills. As a cost-effective alternative to the ever-increasing customer demand, plastic is critical in this process. Throughout the business, the polymer product line has evolved to include products for every segment. Over the years, the use of polymer materials in various industries, from the automobile to the construction sector, has grown. Plastic materials have experienced the greatest benefit in the packaging business. Approximately 300 million tonnes of synthetic plastic were produced in 2013, and the industry has continued to develop by an average of 4% annually. There had been a lot of effort in supplying custom manufactured polymer materials to meet every purpose, but little consideration was paid to successful recycling. Plastic pollution reduction options are presented in decreasing order of environmental safety, with the least environmentally safe choice being landfill [1].

Reducing plastic consumption, reusing plastic materials, recycling plastic materials, and recovering energy are the tactics that are discussed. The circular economy has been hampered in specific ways because of the obstacles that mechanical recycling faces due to incompatible mixing, diminished mechanical characteristics, and strengthening additives in the process. In the end, thermal recycling or burning are the only two options for disposing of synthetic polymers. It is dangerous for the ecosystem when plastic solid waste accumulates in the environment. Microplastics have emerged as a severe threat to marine life as they are a harmful substance to marine life. It was also discovered in the digestive tracts of marine animals being researched at the time of publication. The concept of

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circular economy is gaining popularity, and it has the potential to significantly reduce the demand for polymers [2]. The European Union's circular economy policy is ambitious in promoting the recycling of post-consumer plastics. When compared to other types of manufactured materials, the output of plastics has increased by a factor of many. Although it is not harmful to the environment, post-consumer waste disposal is dangerous. In 2015, according to the figures on plastic disposal, recycling reached nine percent of the total output and incineration obtained 12%. In addition to recycling, landfills have been used to dispose of the remaining post-consumer plastic waste [3].

The amount of plastic solid waste that enters the marine environment has been analyzed, and the potential threats to marine life have been identified as being very high. It is projected that waste management strategies will be adopted by all nations, resulting in a reduction in the amount of garbage produced. It is possible to limit landfills and trash overflow into the marine environment by recycling plastic solid waste. Plastic trash may be converted into energy, which can be used to provide a sustainable solution for post-consumer plastics. Improved collecting, sorting, and recycling processes will help to minimise the amount of waste that ends up in landfills in the future [4]. When compared to landfills, the recovery of energy from post-consumer plastic results in significant cost savings. The amount of energy saved has been adequate, and this encourages the development of a model for post-consumer plastic disposal that includes energy recovery. The added value of energy savings makes the conversion of post-consumer plastic to energy-saving fuels on a large scale a feasible alternative for large-scale industrial transformation.

Plastic recycling has seen significant advancements in recent years thanks to adopting ideas such as chemically recyclable polymers. It was accomplished by two forms of chemical recycling: repurposing and depolymerization, both of which are environmentally friendly. It was discovered that several kinds of polyethylene materials might be converted into liquid fuel distillates and waxes under very moderate conditions [5]. It has been tried to recycle plastic waste into construction materials like tiles to get less combustible materials and have great strength. The plastic waste matrix, reinforced with fly ash and a flame retardant, was moulded into composite tiles with varying levels of reinforcement. The energy recovery option from waste plastics has yet to be fully exploited by large-scale industrial production, even though renewable energy sources have been employed for a considerable amount of bio-waste [6]. It is possible to create energy fuels from biomass by using techniques such as thermal or catalytic pyrolysis and pyrolysis of biomass mixed with polymers [7]. There is an economic, social, and environmental effect on plastic manufacturing and recycling enterprises, as well as important waste management decision makers [8]. The liquid oil produced by this pyrolysis method had low oxygen and nitrogen content and was sulphur-free, resulting in "cleaner" qualities in terms of reduced char residues, sludge formation, corrosiveness, oil quality deterioration, and emission during burning [9-10]. This study aims to provide a summary for recovering energy from waste plastics, which might be used as an alternative fuel for vehicles in the near future.

2. TYPES OF PLASTICS

Depending on the ultimate use, the plastic materials available on the market have a wide range of chemical compositions. For plastics to meet the requirements of any application, they must be designed to have a long service life, high strength, and good aesthetics. Polypropylene, high-density polyethylene, low-density polyethylene, styrene, polyethylene terephthalate, and polyvinyl chloride are the most prevalent types of plastics available on the market today. Carbohydrates and hydrogen are the essential ingredients of plastic polymers, with chlorine being an extra component in the case of PVC. Carbon and hydrogen compounds are the building blocks of polymers, but the chemical structure of one kind differs from the other, making them distinct from one another. Proximate analysis is performed in order to identify the breakdown components of plastics [11].

Attempts have been made to use recycling as a waste administration approach to foster the circular economy. The mechanical technique for recycling plastic waste consists of remelting the product, either on its own or with base feedstock, to create a new product. Before remelting, the plastic waste materials are cleaned, dehydrated, crystallized, and crushed before being melted down again. Thermal-mechanical degradation of the polymer results in the formation of a product that lacks the qualities of a base polymer [12]. It has been discovered that the anticipated strength requirements are lower than expected. While mechanical recycling is a viable alternative for recovering materials and costs from waste, the limited recycling durations and eventual product degradation make the technology unsuitable for use in the plastics recycling industry. There is, without a doubt, an urgent need to develop feasible synthetic waste management solutions in order to meet the varied reusability requirements of the circular economy [13].

3. RECOVERY METHODS

3.1 Chemical Recycling

Chemical recycling is the process of recovering the monomer component from synthetic waste by using a chemical approach. Chemical recycling may be achieved using a range of different chemical techniques, such as thermal or catalytic pyrolysis, for example. When comparing chemical recycling to mechanical recycling, the advantages of chemical recycling may be three times greater. Obtaining unprocessed pure feedstock while keeping the material's original qualities is a challenging task [14]. We have the ability to create valuable chemicals out of waste. It eliminates the problems of material degradation that have been found in mechanical recycling. Ultimately, we want to accomplish energy recovery, and the process of energy recovery should cause as little harm to the environment as possible. Net energy savings are realised during the conversion of solid waste to electricity. Pyrolysis is a process that makes it easier to produce liquid fuel from waste. The transformation of plastic waste into energy may be accomplished by either thermal or catalytic pyrolysis methods [15].

3.2 Pyrolysis Process

Plastic materials are usually non-biodegradable, and they may remain in the environment for up to a hundred years or more. Grouping and milling are two standard recycling procedures that, depending on the method used, can only recover 15 to 20% of total plastic trash. Much interest is being shown in energy recovery techniques such as thermal and catalytic pyrolysis, gasification, and plasma arc gasification, all potential alternatives to conventional synthetic cycle methods [16-17]. Thermal breakdown occurs at high temperatures of 600 °C and results in the transformation of synthetic waste into solid residue char, liquid oil, and gases. Pyrolysis is a recycling technique in which synthetic plastics are converted into char, liquid oil, and gases by the process of heat breakdown, as opposed to other recycling methods [18].

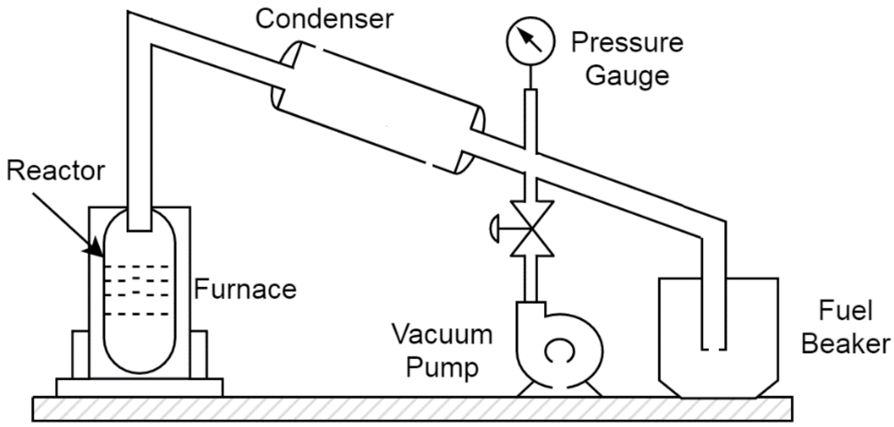

Fig. 1. Schematic layout of pyrolysis process setup [19]

3.3 Thermal Pyrolysis

Thermal pyrolysis, also known as non-catalytic pyrolysis, is a process that absorbs energy without the need for any catalysts. Using thermal pyrolysis has been possible to produce a wide variety of synthetic materials in the past, including polystyrene, polypropylene, and polyethylene plastics. Aside from that, there have only been a few study publications on polyurethane, polymethyl methacrylate, polyethylene terephthalate, and polyvinyl chloride pyrolysis. Compared to LDPE, HDPE, and polypropylene pyrolysis, thermal pyrolysis of polystyrene was conducted with ease, but polyethylene and polypropylene required much higher temperatures for conversion [20]. Furthermore, without the use of a catalyst, polyethylene is converted into waxes rather than liquid oil. During heat pyrolysis, heavy molecules containing carbon chains are formed, resulting in oil formation. Chemically synthesized polymers have high carbon number molecules that, if pyrolysis, will convert into liquids before eventually gelling and solidifying into the wax. Because it cannot break down higher carbon molecules into lower carbon ones, thermal pyrolysis has several limitations in its use. The use of electricity via thermal pyrolysis is more significant than the catalytic method since higher reaction temperatures. Heat-induced pyrolysis produces liquid/wax fuel, non-condensable hydrocarbon gases, and carbonaceous char, among other things. The temperatures ranging from 350□C are effective for catalytic pyrolysis. Plastic conversion achieved by thermal pyrolysis is often a reaction with low selectivity, but conversion achieved through the catalytic method has a higher selectivity [21].

3.4 Catalytic Pyrolysis

The catalytic process is characterised by the use of a catalyst to effect conversion. The pyrolysis of plastic waste involves a number of process factors, such as temperature, heating rate, catalyst usage, particle size, retention time, moisture content, and feedstock composition, amongst other things. Compared to thermal pyrolysis, the technique indicated a high likelihood of the transformation of synthetic waste into oil and improved quality at lower reaction durations and temperatures than previously thought [22]. These parameters have the potential to reduce energy consumption while increasing the output of the whole pyrolysis method. The use of several catalysts, such as aluminium hydroxide, calcium hydroxide, and natural zeolite, Compared to thermal pyrolysis, compounds derived from various types of plastic pyrolysis, such as polystyrene, polypropylene, HDPE, and LDPE, are produced with low carbon numbers, including hydrocarbons containing gasoline range. Furthermore, when comparing catalytic conditions to thermal pyrolysis, the conversion rate was shown to be higher even at lower temperatures [23].

The catalytic mechanism is stated to consist of four chemical reactions. The first is initiation, which involves adding a proton to an on-chain carbonium ion to convert an olefinic bond into an on-chain carbonium ion. Beta scission is a mechanism for breaking up a complicated chain after the initiation stage. Depropagation includes shattering long chains with acidic site attacks and dividing them with beta scission, resulting in a liquid fraction with reduced carbon elements. The third step is isomerization, which involves rearranging carbonium ion components with the help of hydrogen. Aromatization is the fourth step, which consists of the cyclization of carbonium ion components. Compared to thermal pyrolysis, catalytic pyrolysis produces better quality products. Increased pore diameters and moderate acidity in catalysts increase product selectivity. The adoption of a two-step catalytic plastic pyrolysis process improved results [24].

4. CONCLUSION

Water-soluble hydrocarbons, such as those present in plastic, provide a good fuel source. The disposal of waste plastic presents a huge potential for energy conservation and the conservation of energy. When waste plastic is pyrolyzed, it can be utilised to generate energy for fuel production while also being environmentally friendly and cost-effective. Pyrolysis is a process of recovering energy from waste plastic that can repurpose waste plastic as a source of energy for fuel production. A common belief is that the use of pyrolysis is the only realistic means of permanently removing plastic trash from the environment. Diesel fuels are widely used in various industries, including the automotive, agricultural, and power generation sectors, which benefit from higher thermal efficiency and better fuel economy than conventional fuels. It is typically a great experience to look for alternative fuel sources. This study summarises the possibility of recovering energy from discarded plastics as an alternative fuel source.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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