FUEL FROM PLASTIC WASTE

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The present rate of economic growth is unsustainable without saving of fossil energy like crude oil, natural gas, or coal. There are many alternatives to fossil energy such as biomass, hydropower, and wind energy. Also, suitable waste management strategy is another important aspect. Development and modernization have brought about a huge increase in the production of all kinds of commodities, which indirectly generate waste. Plastics have been one of the materials because of their wide range of applications due to versatility and relatively low cost. Recycling can be divided into four categories: primary, secondary, tertiary, and quaternary. As calorific value of the plastics is comparable to that of fuel, so production of fuel would be a better alternative. So the methods of converting plastic into fuel, specially pyrolysis and catalytic degradation, are discussed in detail and a brief idea about the gasification is also included. Thus conversion of plastic waste into fuel can address the problem of plastic waste disposal and shortage of conventional fuel and thereby help in promotion of sustainable environment.

1. Introduction

The increase in use of plastic products caused by sudden growth in living standards had a remarkable impact on the environment. Plastics have now become indispensable materials, and the demand is continually increasing due to their diverse and attractive applications in household and industries. Mostly, thermoplastics polymers make up a high proportion of waste, and this amount is continuously increasing around the globe. Hence, waste plastics pose a very serious environmental challenge because of their huge quantity and disposal problem as thermoplastics do not biodegrade for a very long time.

The consumption of plastic materials is vast and has been growing steadily in view of the advantages derived from their versatility, relatively low cost, and durability (due to their high

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chemical stability and low degradability). Some of the most used plastics are polyolefins such as polyethylene and polypropylene, which have a massive production and consumption in many applications such as packaging, building, electricity and electronics, agriculture, and health care [1]. In turn, the property of high durability makes the disposal of waste plastics a very serious environmental problem, land filling being the most used disposal route. Plastic wastes can be classified as industrial and municipal plastic wastes according to their origins; these groups have different qualities and properties and are subjected to different management strategies [2, 3].

Plastic materials production has reached global maximum capacities leveling at 260 million tons in 2007, where in 1990 the global production capacity was estimated at 80 million tons [1]. Plastic production is estimated to grow worldwide at a rate of about 5% per year [4]. Polymer waste can be used as a potentially cheap source of chemicals and energy. Due to release of harmful gases like dioxins, hydrogen chloride, airborne particles, and carbon dioxide, incineration of polymer possesses serious air pollution problems. Due to high cost and poor biodegradability, it is also undesirable to dispose by landfill.

Recycling is the best possible solution to the environmental challenges facing the plastic industry. These are categorized into primary, secondary, tertiary, and quaternary recycling. Chemical recycling, that is, conversion of waste plastics into feedstock or fuel has been recognized as an ideal approach and could significantly reduce the net cost of disposal. The production of liquid hydrocarbons from plastic degradation would be beneficial in that liquids are easily stored, handled, and transported. However, these aims are not easy to achieve [4]. An alternative strategy to chemical recycling, which has attracted much interest recently, with the aim of converting waste plastics into basic petrochemicals is to be used as hydrocarbon feedstock or fuel oil for a variety of downstream processes [3]. There are different methods of obtaining fuel from waste plastic such as thermal degradation, catalytic cracking, and gasification [3, 5].

2. Methods of Converting Plastic to Fuel

2.1. Pyrolysis/Thermal Degradation

Pyrolysis is a process of thermal degradation of a material in the absence of oxygen. Plastic is fed into a cylindrical chamber. The pyrolytic gases are condensed in a specially designed

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condenser system, to yield a hydrocarbon distillate comprising straight and branched chain aliphatic, cyclic aliphatic, and aromatic hydrocarbons, and liquid is separated using fractional distillation to produce the liquid fuel products. The plastic is pyrolysed at 370°C–420°C.

The essential steps in the pyrolysis of plastics involve(1)evenly heating the plastic to a narrow temperature range without excessive temperature variations,(2)purging oxygen from pyrolysis chamber,(3)managing the carbonaceous char by-product before it acts as a thermal insulator and lowers the heat transfer to the plastic,(4)careful condensation and fractionation of the pyrolysis vapors to produce distillate of good quality and consistency.

Advantages of pyrolysis process [5] are(a)volume of the waste is significantly reduced (<50–90%),(b)solid, liquid, and gaseous fuel can be produced from the waste,(c)storable/transportable fuel or chemical feed stock is obtained,(d)environmental problem is reduced,(e)desirable process as energy is obtained from renewable sources like municipal solid waste or sewage sludge,(f)the capital cost is low.There are different types of pyrolysis process. Conventional pyrolysis (slow pyrolysis) proceeds under a low heating rate with solid, liquid, and gaseous products in significant portions [5]. It is an ancient process used mainly for charcoal production. Vapors can be continuously removed as they are formed [5]. The fast pyrolysis is associated with tar, at low temperature (850–1250 K) and/or gas at high temperature (1050–1300 K). At present, the preferred technology is fast or flash pyrolysis at high temperatures with very short residence time [5]. Fast pyrolysis (more accurately defined as thermolysis) is a process in which a material, such as biomass, is rapidly heated to high temperatures in the absence of oxygen [5].

Potential Applications of Pyrolysis Products

The liquid oil produced from the catalytic pyrolysis of different types of plastic feedstock has a high number of aromatic, olefin, and naphthalene compounds that are found in petroleum products. Moreover, the HHV of the produced liquid oil has been found in the range of 41.7–44.2 MJ/kgwhich is very close to the energy value of conventional diesel. Thus, the pyrolysis liquid oil produced from various plastic wastes has the potential to be used as an alternative source of energy. The production of electricity is achievable using pyrolysis liquid oil in a diesel engineused .Pyrolytic liquid oi lcan also be as an alternative in a kerosene stove. Moreover, the produced aromatic compounds can be used as raw material for polymerization in various chemical industries. Furthermore, various researchers utilized the produced liquid oil as

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transportation fuel after blending with conventional diesel at different ratios. The studies were carried out to explore the potential of produced liquid oil in the context of engine performance and vehicle exhaust emission and it has been reported that 20:80% blend ratio of pyrolytic liquid oil and conventional diesel, respectively, gave similar engine performance results than conventional diesel. Moreover, at the same blended ratio the exhaust emissions were also similar, however the exhaust emissions increased with the increase in the blended amount of pyrolysis oil.

2.2. Catalytic Degradation

In this method, a suitable catalyst is used to carry out the cracking reaction. The presence of catalyst lowers the reaction temperature and time. The process results in much narrower product distribution of carbon atom number and peak at lighter hydrocarbons which occurs at lower temperatures. The cost should be further reduced to make the process more attractive from an economic perspective. Reuse of catalysts and the use of effective catalysts in lesser quantities can optimize this option. This process can be developed into a cost-effective commercial polymer recycling process for solving the acute environmental problem of disposal of plastic waste. It also offers the higher cracking ability of plastics, and the lower concentration of solid residue in the product [3].

Various chemical processes invoved in the Catalytic Degradation are given below.

1. Initiation. Initiation may occur on some defected sites of the polymer chains. For instance, an olefinic linkage could be converted into an on-chain carbonium ion by proton addition:The polymer chain may be broken up through β-emission:Initiation may also take place through random hydride-ion abstraction by low-molecular-weight carbonium ions. The newly formed on-chain carbonium ion then undergoes β-scission.

2. Depropagation. The molecular weight of the main polymer chains may be reduced through successive attacks by acidic sites or other carbonium ions and chain cleavage, yielding ingan oligomer fraction (approximately C_{30}–C_{80}). Further, cleavage of the oligomer fraction probably by direct β-emission of chain-end carbonium ions leads to gas formation on one hand and a liquid fraction (approximately C_{10}–C_{25}) on the other.

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3. Isomerization. The carbonium ion intermediates can undergo rearrangement by hydrogen- or carbon-atom shifts, leading to a double-bond isomerization of an olefin:Other important isomerization reactions are methyl-group shift and isomerization of saturated hydrocarbons.

4. Aromatization. Some carbonium ion intermediates can undergo cyclization reactions. An example is when hydride ion abstraction first takes place on an olefin at a position several carbons removed from the double bond, the result being the formation of an olefinic carbonium ion:The carbonium ion could undergo intramolecular attack on the double bond.

2.3. Gasification

In this process, partial combustion of biomass is carried out to produce gas and char at the first stage and subsequent reduction of the product gases, chiefly CO_2 and H_2O, by the charcoal into CO and H_2. Depending on the design and operating conditions of the reactor, the process also generates some methane and other higher hydrocarbons (HCs) . Broadly, gasification can be defined as the thermochemical conversion of a solid or liquid carbon-based material (feedstock) into a combustible gaseous product (combustible gas) by the supply of a gasification agent (another gaseous compound). The gasification agent allows the feedstock to be quickly converted into gas by means of different heterogeneous reaction. If the process does not occur with help of an oxidising agent, it is called indirect gasification and needs an external energy source gasification agent, because it is easily produced and increases the hydrogen content of the combustible gas [5].

A gasification system is made up of three fundamental elements: the gasifier, helpful in producing the combustible gas; the gas clean up system, required to remove harmful compounds from the combustible gas; the energy recovery system. The system is completed with suitable subsystems, helpful to control environmental impacts (air pollution, solid wastes production, and wastewater).

Gasification process represents a future alternative to the waste incinerator for the thermal treatment of homogeneous carbonbased waste and for pretreated heterogeneous waste.

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3. Summary

Plastics are "one of the greatest innovations of the millennium" and have certainly proved their reputation to be true. Plastic is lightweight, does not rust or rot, is of low cost, reusable, and conserves natural resources and for these reasons, plastic has gained this much popularity. The literature reveals that research efforts on the pyrolysis of plastics in different conditions using different catalysts and the process have been initiated. However, there are many subsequent problems to be solved in the near future. The present issues are the necessary scale up, minimization of waste handling costs and production cost, and optimization of gasoline range products for a wide range of plastic mixtures or waste.

Huge amount of plastic wastes produced may be treated with suitably designed method to produce fossil fuel substitutes. The method is superior in all respects (ecological and economical) if proper infrastructure and financial support is provided. So, a suitable process which can convert waste plastic to hydrocarbon fuel is designed and if implemented then that would be a cheaper partial substitute of the petroleum without emitting any pollutants. It would also take care of hazardous plastic waste and reduce the import of crude oil.

Challenge is to develop the standards for process and products of postconsumer recycled plastics and to adopt the more advanced pyrolysis technologies for waste plastics, referring to the observations of research and development in this field. The pyrolysis reactor must be designed to suit the mixed waste plastics and small-scaled and middle-scaled production. Also, analysis would help reducing the capital investment and also the operating cost and thus would enhance the economic viability of the process

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