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Pyrolysis of Municipal Plastic Waste to Produce Alternate Fuel

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Abstract

This research concentrates on the pyrolysis of municipal plastic waste (MPW) to produce an alternate fuel and its thermal comparison with petrol and diesel. It is a viable response to the growing problem of plastic waste disposal. Fuels made from petroleum and plastics contain carbon and hydrogen and are classified as hydrocarbons. Plastics are made up of fossil fuel-based chemicals such as natural gas or crude oil. It is non-biodegradable waste, mainly consisting of approx 15% of total Municipal Solid Waste (MSW). Plastics are pivotal in today's world and are excessively used in households, industry and other fields due to their lightweight, durability, flexibility and inexpensive ability to produce. The need for plastics is expanding every day, posing a significant danger to the climate.

The pyrolysis process is a waste-to-energy technological option for producing alternative fuels to replace fossil fuels. It is a thermochemical decomposition of organic material at high temperatures without oxygen or an inert gas atmosphere. Municipal Plastic Waste is depolymerized, pyrolyzed, catalytically cracked, and fractionally distilled to produce various value-added petroleum-derived fuels via pyrolysis which can be used to replace low diesel oils. The pyrolysis method has the benefit of being able to handle unsorted polymers. The material's pretreatment is simple. Plastics must be sorted, dried, and shredded. Pyrolysis, instead of incineration, doesn't emit harmful or hazardous gases. Transforming municipal plastic waste into energy has significant environmental, climatic, and economic implications.

Keywords: Municipal solid waste, Municipal plastic waste, Pyrolysis, Energy, Alternate fuel.

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Introduction

Plastics are rapidly growing components of municipal solid waste. They are widely used in our daily life. Their nature of being lightweight, flexible, durable and inexpensive to produce has led to their widespread use. Thus, making it a major concern for disposal. Municipalities are facing issues with dumping plastic waste as there are limited landfill sites left for sanitation workers to dump the plastic.

The main objective is to use municipal plastic waste as an alternate source of energy in the form of combustion oil. Over 100 million tonnes of plastic are manufactured globally each year. In India, plastic waste amounts to roughly 10,000 tonnes every day. Hence, an alternative fuel can help reduce environmental pollution and meet the demand for increased fuel energy.

Plastics

Plastics are a class of synthetic or semi-synthetic materials that are mostly composed of polymers. They are created by the polymerization or polycondensation process from natural elements such as cellulose, coal, salt, and crude oil. They are simply molded, extruded or solidified into various sizes and shapes. They are made from the human industrial system by the cracking process.

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Plastics are classified into two types

Thermoplastics

Thermoplastics are recyclable polymers that can be softened and melted again when heated and solidified when cooled, allowing them to be recycled into new plastic items. Polyethene terephthalate(PET), polystyrene(PS) polyvinyl chloride(PVC), high-density polyethylene (HDPE), low-density polyethene (LDPE), polypropylene(PP), and others are examples.

Thermosetting plastic

Thermosets are common names for thermosetting polymers. They're only melted and formed once. It is not advisable to heat such polymers repeatedly, as this causes them to remain solid after solidification. Phenol formaldehyde, epoxy resin, and urea-formaldehyde are examples of thermosets.

Muncipal Plastic Waste

Municipal plastic waste (MPW), discharged and collected as residential, industrial, institutional, agricultural and commercial garbage, typically remains a component of municipal solid waste (MSW). Plastics, such as food receptacles, dairy/milk, water and shampoo bottles and lids, packing foam, single-use cups, cutlery and plates, comprise the bulk of MPW. Additionally, temporary plastics used as flooring, surface coatings, refrigerator liners, vending cups, feed bags, fertilizer bags, electronic equipment compartments, drainage pipes, beverage bottles, plumbing pipes, and coverings for hay, silage, wire, and cable, among other items, add to MPW. In this way, the plastic trash that MPW gathered is combined with a significant amount of HDPE, LDPE, PP, PVC, PET, PS, etc. Municipal Solid Waste differs from place to place in its percentage of plastics, but it is steadily rising.

Pyrolysis

The word "pyrolysis" refers to the thermal deterioration of materials at higher temperatures without oxygen (or in an inert atmosphere). It is a chemical reaction in which larger molecules disintegrate into smaller ones when heat is present. The process is irreversible and includes a variation in mixture organization. The words "pyro" and "lysis" are two Greek words that signify "fire" and "isolating.

The treatment of organic materials via pyrolysis is its most popular use. Starting at temperatures between 350 and 500°C, it is one of the procedures used to char wood. When organic materials are pyrolyzed, they release volatile byproducts and a solid, carbon-rich residue known as char. Extreme pyrolysis produces a residue known as carbonization, which consists mostly of carbon.

The pyrolysis procedure also has extensive uses in the chemical sector. It is used to deliver ethylene, various kinds of carbon, and other chemicals from oil and coal, for example, when making coke from coal. The conversion of municipal plastic waste into useable oil or rubbish into compounds that may be disposed of properly is an aspirational application of pyrolysis.

Pyrolysis is distinct in comparison to other high-temperature procedures like hydrolysis and ignition. It often excludes the expansion of certain reagents, such as oxygen (O2, in burning) or water (in hydrolysis). However, since some quantity of oxygen is constantly present and causes oxidation, producing oxygen- or water-free conditions is frequently impractical.

Methodology

The flow chart makes up the methodology (Figure 1).

Municipal Plastic Waste Collection

Municipal plastic waste collection is simple since shredded debris plastics are readily available in large quantities at the municipality collection location. These are generally mixed HPDE, LDPE, PET, PP, PS and PVC plastics.

Pyrolysis Process

The pyrolysis method is used to extract fuel from MPW. In this method, shredded municipal plastic waste is fed into the reactor and is rapidly heated in an oxygen-free reactor to temperatures ranging from 350 to 500°C. When the melting point is achieved, the plastic melts and the vapor rises to the condensing unit. The vapor is condensed using water. The condensed vapor turns into liquid fuel and is collected in a vessel, while the uncondensed gases are returned to the furnace for heating. Municipal plastic waste pyrolysis produces a combination of fuel, gases, and solid char. The percentage of these three products will vary depending on the pyrolysis method, the type of plastic utilized, and the temperature (Table 1).

The key components of the pyrolysis setup are as follows:

Reactor: The 20 kg steel cylinder serving as a container can withstand temperatures of up to 850°C and hold up to 15 kg of plastic shreds.

Furnace: Used to heat the reactor and provide the necessary flame temperature to melt the polymers inside the reactor.

Condenser Unit: At temperatures ranging from 350 to 500°C, municipal plastic waste evaporates. About 80% of the vapor is condensed to ambient temperature using a tube condenser.

Pipes: The pipes are connected through the water tank, condenser and outlet. Water is transported by the use of a normal motor to the condenser unit for condensation. The condensed oil is collected in a vessel, whereas the uncondensed gas is then transferred from the condensing unit to a steel rod installed near the furnace to generate the flame.

Collecting Vessel: Used to collect the extracted oil that has condensed in the condenser unit.

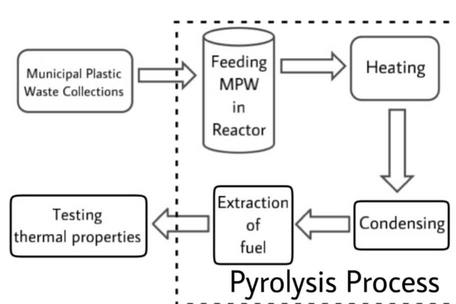

Figure 1: Methodological representation

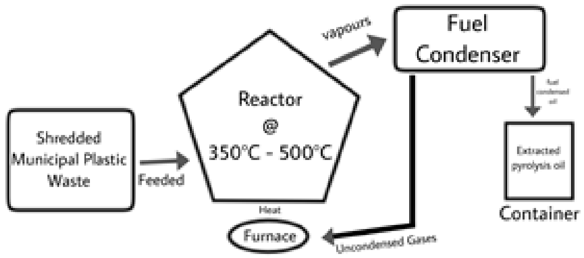

Figure 2: Schematic representation of extraction of fuel from MPW

Extraction of Fuel from the Municipal Plastic Waste

Municipal plastic waste shreds were cleaned, dried, and then added to a pyrolysis reactor unit. For one hour and thirty minutes, the procedure was conducted outside of the reactor at elevated temperatures between 350 and 500°C. A condenser that uses water cooling receives the pyrolysis's vapor-based waste products. Where fuel-grade condensate is gathered and utilized. Figure 2 depicts the method and setup to extract fuel. The fuel gathered was in crude form (Table 2).

Testing Thermal Properties of the Extracted Fuel (plastic pyrolysis oil)

The extracted fuel has a thick fluid appearance with brownish-yellow color shading and has an appalling odor. Some of the thermal properties of the extracted fuel from Municipal plastic waste pyrolysed oil tested are listed below.

Density

The proportion of fuel mass to fuel volume is density. It has the SI unit (kg/m^3). Thus, the density of the plastic extracted plastic pyrolysis oil came out to be 770 kg/m^3.

Kinematic Viscosity

Kinematic viscosity is the ratio of the fluid's two physical properties. It is described as the correlation between a fluid's density and dynamic viscosity. The centistoke (cst) is its SI unit. The viscometer is used to calculate the kinematic viscosity. As a result, the extracted plastic pyrolysis oil had a kinematic viscosity of 1.99 cst at 40°C.

Gross Calorific Value:

The amount of heat liberated by the combustion of a unit volume of gas is the gross calorific value. It is measured in MJ/kg. As a result, the extracted plastic pyrolysis oil had a gross calorific value of 47.5 MJ/kg.

Flash and Fire Point

The minimum temperature for a fluid to create an ignitable mixture in the air close to its surface is known as the flashpoint. And the temperature below which a liquid's vapour will start and maintain a combustion reaction is fire point. °C is its SI unit. To determine the value for flash and fire point, extracted fuel is to be heated and monitored after putting into the flash point apparatus. The outer fire is introduced up until the flash is achieved. And The reading is recorded after receiving the flash to achieve fire point. A temperature of 28 and 32°C results in the flash point and fire point.

Table 1: Experimental outcome on pyrolysis of municipal solid waste

Particular	*Test 1*	*Test 2*	*Test 3*
Total Mass of plastic used	6kg	8kg	10kg
Total fuel production	5.2l	7.2l	8.9l
total char production	.75kg	.76kg	1.05kg
Time of operation	90 min	95 min	95 min

Table 2: Comparison between MPW, Petrol and diesel

Sno.	*Properties*	*Municipal Plastic Waste Fuel*	*Petrol*	*Diesel*
1	Density (kg/m3)	770	742	832
2	Kinematic viscosity cst @ 40°C.	1.99	2.1	2.5
3	Gross Calorific Value (MJ/kg)	47.5	45.7	45.5
4	Flash Point (°C.)	28	29	48
5	Fire Point (°C.)	32	33	55

Results and Discussion

Following the extraction of the fuel from municipal plastic wastes via the pyrolysis process, the fuel was subjected to a series of tests to assess its properties and evaluate them against traditional fuels. Thermal properties are among the tests performed and the results are further discussed below.

Comparision of Thermal Properties

The thermal properties of extracted fuel are comparable to those of gasoline. The following table compares physical properties such as density, kinematic viscosity at 40°C, gross calorific value, flashpoint, and fire point.

The comparison table makes it clear that plastic pyrolysis oil has characteristics similar to those of petrol and diesel and can be used as a substitute fuel source.

As a diesel equivalent, it can replace low-diesel oil-powered equipment like generators, batch mixing plants and machinery for construction sites.

Conclusion

Municipal plastic waste poses a significant environmental and climate risk. Millions of tonnes of plastic are produced everyday, with only a small percentage of these plastics successfully recycled. Because plastic takes a long time to disintegrate, some alternatives should be developed. In addition, the world is dealing with a petroleum shortage. As a consequence, turning municipal plastic waste into fuel can be a more effective way to address the problem of how to dispose of this waste while simultaneously serving as an alternative to fossil fuels.

Because of this, the issue of managing plastic waste and the dearth of fossil fuels may both be solved by pyrolyzing plastic into fuel.

Waste management becomes more efficient with pyrolysis methods because it is more cost-effective, pollutes less and needs less landfill space. Furthermore, in order to meet the surge in energy demand, it's possible to lessen the dependency on non-renewable fossil fuels by degrading plastic into valuable energy fuel. As a result of the studies, It is feasible to draw the conclusion that diesel-like properties existed in the fuel produced from municipal plastic waste, making it a viable alternative fuel.

Scope of future work

The project is a modest effort to draw attention to the fact that municipal plastic waste can be converted into a different type of energy (fuel). Since it is a research-based project, numerous studies still need to be done. For the fuel to have better qualities, additional purification is required. The process can be accelerated by using a catalyst. Better findings may come from additional research in this area.

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