# Experimental Bio-Fuel Production From Plastic Waste In Sequential Thermo-Catalytic Pyrolysis

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*Abstract:* Environmental concerns of plastic waste management and depletion of fossil oil resources driven us to convert the waste plastics into high quality oils that could replace the fossil fuel. Pyrolysis is a process that can effectively convert plastics waste into fuel. In this, High Density Poly Ethylene and Poly Propylene plastics are pyrolyzed with and without catalyst to get the bio-fuel and to compare the yield and time duration. The liquid oil yield of thermal Pyrolysis on plastic waste is between 70% to 80%. The collected plastics undergo thermal and catalytic Pyrolysis process which is being maintained at 450°C to 600°C in the absence of oxygen and the bio-fuel is extracted. The fuel collected by this process was found to be less than when compared with fuel collected by using the catalyst $BaCl_2$. The percentage of fuel extracted by using catalyst was found to be 40% higher than that of the fuel extracted without using catalyst. In the catalytic Pyrolysis increases the amount of fuel obtained and reduces the time duration.

**Keywords:** Pyrolysis, $Bacl_2$, Bio-fuel, Plastic waste, Catalyst, yield.

## I. INTRODUCTION

Disposal and recycling of waste plastics have become an incremental problem and environmental threat with increase in plastic demand. Majority of plastics that are used today are non-biodegradable in nature, they remain in environment for long period which affects environmental quality. In India, plastic waste accounts to be about fifteen thousand tons per day of generated municipal solid waste. As there is no effective segregation and recycling system for these plastic waste generated, it increases load on landfill sites because of their non-biodegradable nature and ultimately causes environmental problems like air, soil and ground water pollution as well as loss of marine biodiversity. As the disposal of plastic will take more than 500 years in natural way. Hence, the plastic waste disposal is the biggest concern of the city.

To tackle those problem one of the effective measures is by converting waste plastic into combustible hydrocarbon liquid as an alternative fuel for running diesel engines.

### 1.1 GENERATION OF WASTE PLASTIC

Generation of plastic waste in the world is increasing continuously due to Industrial growth and changed in consumption and production patterns. Rapid urbanization and economic development have been resultant as increment in plastic consumption in Asia pacific and other developing regions. Due to higher population growth rate waste plastic and its management has become a major problem. Cities having low economic growth are also participating as larger producer of waste plastic in the form of plastic packaging material, poly shopping bags, P.E.T. bottles and other house hold items containing major percentage of plastic material. So it is necessary to find the alternative ways for the disposal of mixed waste plastic. After so many research and studies it has been found that properties of crude oil derived from waste plastic are similar to the existing hydrocarbons and can be used in diesel engines or for energy production.

Approximately 85 to 90% of plastic from our daily life can be recycled or use for the production of synthetic fuel. In order to decrease the volume of non-degradable plastic waste material and preserving valuable petroleum resources .Pyrolysis is one of the best methods. It is also help full in environmental protection. Because of higher conversion rate of fuel from plastic waste pyrolysis process is in favored. However, the great number of consumptions would increase the product of plastics wastes which led to the environmental problems. Land filling is not a suitable option for disposing plastic wastes because of their slow degradation rates. The use of incinerator generates some pollutants to the air, which also cause environmental issues. Therefore, recycling and recovering methods have been used to minimize the environmental impacts and to reduce the damage of plastic wastes.

1.2 *Plastic*: Plastics are synthetic organic material and mainly produced by polymerization. Molecular mass of plastic is high and it is possible that to improve the quality and performance and to reduce the cost plastic may contain other substances. Polymers of Plastic are much softened and can be extruded into required shapes. They can be shaped by heat or pressure

1.3 *Catalyst*: A substance which increases the rate of reaction without itself undergoing any permanent chemical change. We use a Barium chloride as catalyst for this experiment. It precipitates the solid from liquid which may leads to easy process. It converts liquid state into gaseous form quickly. so, it reduces the time duration. Barium chloride is the inorganic compound with the formula $BaCl_2$. It is one of the most common water-soluble salts of barium. It is inflammable. It can be used for the purification of the liquids. It will easily convert the gas into the liquid.

1.4 *Thermal Degradation Process*: Traditional treatments for post-consumed plastics were recycled, land filled or incinerated. However, landfill of the post-consumed plastics has potential problems because of limited land resource and high durability of plastics. Incomplete incineration may generate poisonous substances and causes serious health problems. Other methods like gasification and bioconversion are mainly used for organic materials. Therefore, significant amount of energy can be produced by converting plastic waste to oil. This could be an alternative energy resource for substituting fossil fuels.

1.5 *Pyrolysis*: Pyrolysis is the process of Heating with high temperature and pressure without water and oxygen. To obtain bio-fuel, anhydrous pyrolysis is used. It maintained above 350+°C at pressure >12MPa. It gives a product of Bio-char, light crude, gaseous alkenes.

1.5.1 *Pyrolysis Process*: In the pyrolysis process, plastic waste is first converted to the molten state and then ‘cracked’ in a stainless steel chamber at temperatures in the range 350–425°C under inert gas The hot pyrolytic gases are condensed in a specially designed two-stage condenser system to yield a hydrocarbon distillate comprising straight-chain and branched-chain aliphatics, cyclic aliphatics and aromatic hydrocarbons. The resulting mixture is essentially equivalent to regular diesel.

The essential steps in the Thermo fuel pyrolysis of plastics involve

- Uniformly heating the plastic within a narrow temperature range without excessive temperature variations.
- Ensuring the plastic is homogeneous and stirred to prevent hot-spots.

Polymers are chopped and heated without oxygen undergoes condensation then the fume converts into bio-fuel which was tapped. It may produce short chain fuel products (Gasoline, Fuel) and Esters are formed (Diesel) with addition of catalyst. Sorting the plastics, it is chopped and loaded into reactor vessel.

## 2. MATERIALS AND METHODS

The sample was collected from individual households which is a mixed plastic. Mixed plastics are HDPE, LDPE & PP. The waste that is generated from individual residents are collected and weighed to get approximate.

*A. Stage 1*

Polymers are chopped and heated without oxygen undergoes condensation; the fume converts into bio-fuel which was tapped. It may produce Short chain fuel products (Gasoline, Fuel) and Esters (Diesel) with addition of catalyst. Sorting the plastics, it is chopped and loaded into reactor vessel. This process contains three stages,

*Type 1*: Pyrolysis without catalyst

Only raw plastics are feed into the reactor to undergo the pyrolysis process. In this type, the catalyst is not added to the polymer to find the yield of the liquid oil, time duration and their effectiveness. 200gm of plastics from each type is taken separately and processed separately.

*Type 2*: Pyrolysis with catalyst

The raw plastics are feed into reactor with adding catalyst Barium chloride into it. In this type, the catalyst is added to find and comparing the yield of the liquid oil, time duration and their effectiveness. It may increase the yield and decrease the duration. 200gm of plastic is added with 20gm of barium chloride for each plastic type and processed separately. The ratio of plastics and catalyst is 10:1.

Step 1: Collection of plastics- The material was collected from individual households and was categorized according to the plastic recycling code. The collection of waste plastic is quite an easy task as compared to other wastes. The plastic wastes are abundant and can be obtained in large quantities from the households, roadsides, hospitals, hotels etc. The plastics taken for our project are HDPE, LDPE and PP.

Figure 2.1 Collection of materials

Step 2: Segregation and shredding of plastics: The collected plastics are segregated and it is separated according to their types. These plastics are shredded and finely chopped into small pieces.

Figure 2.2 chopping the plastics

Step 3: Experimental setup: The pyro-reactor was designed based on small scale generation of plastic waste. The set up consist of a heating source, reactor crucible, condenser sealed with reactor at one end and another end was feed into a collection flask the water is supplied to the condenser.

Figure 2.3 Experimental setup

B. *Stage 2*

In this stage, the vessel is sealed and connected with condenser. and heated to above 350°C to 400°C. Maintain the pressure more than 12MPa. There is no oxygen supply into the reactor and make the process anaerobic decomposition. Polymers is starting to de-polymerize into light crude liquid.

Step 1: Feed Plastics with and without catalyst

1. After the reactor set up, the waste is processed to extract the plastic fuel. The plastic waste collected was feed into the reactor at top end and connected with coil condenser. Then the condenser is feed into the receiving flask.
2. The plastics like high density polyethylene, low density polyethylene, poly propylene are each taken 200gm and feed separately.
3. These plastics are first feed without catalyst undergoes thermal pyrolysis to compare with the catalytic pyrolysis.
4. In second process of the same plastics, the collected plastics are feed into the reactor with adding catalyst Barium chloride.
5. The temperature was fixed ranges from $350^0$C -$500^0$C.
6. The temperature should be adjusted till the plastic reaches the molten phase to gaseous phase.
7. The Polymers are heated under pressure without oxygen, fumes are formed inside the flask.

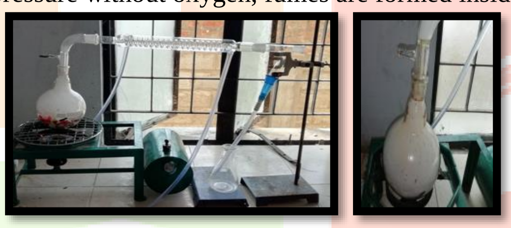

Figure 2.4 Feed plastics into the reactor and heats the plastics

C. *Stage 3*

The fume started to convert into liquid through the condensation. Finally, the fuel is tapped into the container the product obtain from the process are,

- Hydrocarbon fumes can be burnt as Synthesis gas.
- Light crude oil and bio-fuel is obtained.
- Bio-char solids can be used on farm fields.

Figure 2.5 formation

Step 2: Condensing of Hydrocarbon gas

After the reaction for certain time the plastic is converted into liquid state, and then it is changed into vapor state and passes through condenser.

- The fumes are passes through the coil condenser.
- Gas bubbles from the coil condenser react with water low temperature supplied from tap into the condenser and float over the surface as the density of the oil was greater than that of water.
- Finally it was converted into liquid fuel which is collected into the collector flask containing water and then the outcome of the product from the pyrolysis process was extracted and was kept for further analysis.

The products obtained from the anhydrous pyrolysis are,

Figure 2.6 Tapping of fuel and Bio- char

Likewise, the all types of polymers chosen are undergone the three stages. It obtains fuel from adding both catalyst and without catalyst. It produced above 70% of fuel. The fuel of HDPE, PP, and LDPE are varying in color and viscosity. At the same time the color and viscosity are also differ when adding catalyst.

Figure 2.7 Bio-fuel of HDPE, LDPE, PP

## 3. RESULTS AND DISCUSSIONS

### 3.1 Properties of Waste Plastics

The properties of waste such as HDPE, LDPE & PP were determined. The physical properties such as Density, Melt flow index and Melting point of LDPE was taken. The characterization for the waste plastics was carried out to determine the maximum yield for the process. The maximum efficiency for the thermal degradation process was obtained by selecting the maximum percentage range of suitable plastics of about 50% HDPE, 25% LDPE AND 25% PP waste.

**1. High Density Polyethylene Waste Plastics**

The density of HDPE waste plastic should be in the range of 0.93-0.97 g/cm$^3$. The melt flow index is the measure of ease of flow of the melt of a thermoplastic polymer and the value obtained is 2.16 kg. The melting temperature is high when compared with other two polymers. The result was discussed below in table 3.1

**Table 3.1 Physical properties of feedstock (HDPE)**

| Properties | Units | Values |
|---|---|---|
| Density | g/cm$^3$ | 0.97 |
| Melt flow index | g/10min | 2.16 |
| Tensile strength | mPa(psi) | 37 |
| Average molecular weight | Daltons | 80,000 |
| Melting temperature | ºC | 120-180 |

**2. Polypropylene Waste Plastics**

The density of polypropylene waste plastic should be in the range of 0.80-0.90 g/cm$^3$. The melt flow index is the measure of ease of flow of the melt of a thermoplastic polymer and its value is 1-10 g10/min. The melting temperature is medium when compared with other two polymers. The result obtained was discussed below in table 3.2.

**Table 3.2 Physical properties of feedstock (PP)**

| Properties | Units | Values |
|---|---|---|
| Density | g/cm$^3$ | 0.92 |
| Melt flow index | g/10min | 2.0 |
| Tensile strength | mPa(psi) | 18 |
| Average molecular weight | Daltons | 80,000 |
| Melting temperature | ºC | 118 |

**3. Low Density Polyethylene Waste Plastics (LDPE)**

The density of LDPE waste plastic should be in the range of 0.91-0.94 g/cm$^3$. The melt flow index obtained is 1.8-2.4. The melting temperature range obtained is 115$^0$c, when compared with other two polymers the melting point is low. The physical properties of LDPE waste plastic and its result was compared with the result obtained in this work. The result obtained in this work is in permissible range. The result obtained was shown below in table 3.3.

**Table 3.3 Physical properties of feedstock (LDPE)**

| Properties | Units | Values |
|---|---|---|
| Density | g/cm$^3$ | 0.92 |
| Melt flow index | g/10min | 2.0 |
| Tensile strength | mPa(psi) | 18 |
| Average molecular weight | Daltons | 80,000 |
| Melting temperature | °C | 118 |

The various physical properties of HDPE, LDPE and PP waste plastics, it was concluded that the HDPE has more density range as compared with other plastic chosen for the process. When the density range was high then the yield of the process may raises and the efficiency may increases. Hence the HDPE waste chosen for the process was about 50%.

### 3.2 FUEL OBTAINED FROM VARIOUS PLASTICS

The fuel obtained from various plastic waste while with catalyst and without catalyst. There is variation in time duration, yield obtain from the process. The below table shows that the amount plastics used, amount of yield obtained, and the time taken to obtain the fuel from the process and amount of catalyst added to it.

**Table 3.4 Fuel obtained from various plastics**

| Input | Qty (g) | Catalyst $BaCl_2$ (g) | Output | Time (mins) | Qty (ml) | Output % |
|---|---|---|---|---|---|---|
| HDPE | 200 | - | Bio-Fuel | 90 | 95 | 47.5 |
| HDPE | 200 | 20 | Bio-fuel | 65 | 185 | 92.5 |
| PP | 200 | - | Bio-Fuel | 110 | 90 | 45 |
| PP | 200 | 20 | Bio-Fuel | 75 | 145 | 72.5 |
| LDPE | 200 | - | Bio-Fuel | 55 | 150 | 75 |
| LDPE | 200 | 20 | Bio-Fuel | 35 | 184 | 92 |

### 3.3 PROPERTIES OF EXTRACTED FUEL

From the thermal and catalytic degradation process of each plastic, the result obtained was discussed below in a table 5.4. The table below shows the properties of extracted fuel from the designed single home scale pyro reactor. The efficiency obtained from the process was about % of mixed plastic waste. The sulphur content was very minimum and hence will not have any effect on the environment.

**Table 3.5 Properties of Pyrolysis fuel**

| Properties | HDPE Fuel | PP Fuel | LDPE fuel |
|---|---|---|---|
| Color, visual | Pale yellow | Pale green | Dark yellow |
| Specific gravity at 28 °C | 0.7425 | 0.7587 | 0.7356 |
| Specific gravity at 15 °C | 0.754 | 0.7525 | 0.7468 |
| Gross calorific value (KJ/g) | 13268 | 13865 | 13254 |
| Net calorific value (KJ/g) | 12289 | 12352 | 12153 |
| API gravity | 60.83 | 58.26 | 59.85 |
| Sulphur content (by mass) | 3.02 | 2.90 | 2.91 |
| Flash point °C | <0.002 | <0.002 | <0.002 |
| Pour point °C | 56 | 56 | 56 |
| Cloud point | <-40 | <-40 | <-40 |

### 3.4 COMPARISON OF EXTRACTED FUEL WITH COMMERCIAL FUEL

The properties of extracted fuel with the regular gasoline were discussed below. The efficiency obtained from the process was about 59.97% of mixed plastic waste was higher when compared with regular gasoline. The sulphur content range was also very minimum when compared with regular available fuel and hence will not have any effect on the environment

**Table 3.6 Comparison of Extracted fuel with Commercial Fuel**

| Properties | Units | Commercial Fuel | Extracted Fuel |
|---|---|---|---|
| Color, visual | - | Orange | Pale yellow |
| Specific gravity @28 °C | °C | 0.7567 | 0.7425 |
| Specific gravity @15 °C | °C | 0.768 | 0.754 |
| Gross calorific value | (KJ/g) | 13410 | 13268 |
| Net calorific value | (KJ/g) | 12460 | 12289 |
| API gravity | - | 54.50 | 60.83 |
| Sulphur content | G | 4 | 2 |
| Flash point °C | °C | 0.1 | <0.002 |
| Pour point | °C | 50-60 | 56 |
| Cloud point | °C | <-40 | <-40 |

## 4. CONCLUSION

Our environment was mostly suffered with the generation of plastic waste. Hence, that thermo-catalytic pyrolysis of plastic waste leads to the production of fuel oil. The following results were obtained from this experimental work,

- The yield obtained by this process was found to be 30 % to 40% higher than that of the yield obtained without catalyst $BaCl_2$.
- Adding catalyst $BaCl_2$, it increases the yield and reduces the time duration.
- The yield is also differing according the density of the polymers. If the density is high the yield is also higher. Hence, the yield of HDPE is higher than the LDPE and PP.
- The property test results were found to be approximately equals with that of the diesel fuel.

Hence, it can be concluded that the oil derived from waste HDPE, LDPE, PP of thermal Pyrolysis on plastic waste is between 70% to 80%. Thermal pyrolysis of waste plastic has also several advantages over other alternative recycling method. It has been shown that the conversion at lower temperature in the presence of catalyst into liquid is a feasible process. It has best possible in decreasing price of fuel in future. It is safe to the environmental and economic scenarios.

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