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# PYROLYSIS OF POLYPROPYLENE PLASTIC WASTE BY INFRARED WAVE

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***Abstract****- The purpose of this study was to perform pyrolysis of polypropylene (PP) plastic by infrared wave. This study was carried out without catalyst. Plastics have been pyrolyzed and liquid fuel has been found. Pyrolysis of polypropylene (PP) was performed in a stainless-steel reactor with a length of 7.62 cm and an inner diameter of 3.69 cm between 320˚C-400˚C temperatures. For pyrolysis, 1 mm-2 mm of recycled polypropylene plastic pellets were used. An infrared cooker was set at 2000-watt for heating the reactor with a reaction time of 70 minutes. The outcome indicates that the highest yield of liquid from 50 g sample was 72 wt.% or 36 g at 360˚C.*

**Keywords:** Pyrolysis, Polypropylene, Infrared, Waste, Reaction time.

## 1. INTRODUCTION

In Bangladesh, pollution from plastic becomes an increasing issue. Particularly the main three towns of Bangladesh namely Dhaka, Chattogram and Sylhet are at great danger. In recent years, manufacturing and usage of various plastic products have been expanded because of homes and industrial needs. In Dhaka, about 14 million polybags are thrown away every day, often ending up in rivers and oceans that put marine life at risk [1]. Bangladesh had experienced floods in urban areas in 1998 and 2008, where polyethene and plastics were one of the main causes of blocking drainage system [2].

One of the main consequences of plastic pollution is its great threat to public health because of toxic chemicals are entering the bloodstream via air, water and food which cause cancer, respiratory diseases, disturbances in the hormone, infertility, birth defects, early puberty, impaired immunity and so on [1]. Production of plastic is increasing globally. With 359 million tons of plastics placed on the global market in 2018, the industry reported an increase of 3.2 % compared to the prior year. Production has more than tripled since 1990 [3].

Traditional methods of plastic waste disposals have been both to bury or burn them in landfill incinerators, respectively. Landfills and incinerators then again related with serious environmental concerns. Pyrolysis can be used to treat plastic waste. Pyrolysis is the thermal breakdown of materials in an inert atmosphere at high temperatures. It involves the change in chemical composition and is irreversible [4]. Pyrolysis products composition is influenced by process operating conditions such as feed size, operating temperature and pressure, reaction time, heating rate and catalytic medium presence. The main advantage of pyrolysis is the reduction in volume of the waste.

Nowadays infrared cooker becomes popular for pyrolysis process. Infrared technology is environmentally friendly [5]. IR ovens are easily constructed. It can also be easily reconfigured [6]. Plastic waste recycling by infrared wave reduces pollution. Plastic demand has been increased every year on the other hand decrease in fossil fuel such as gas, coal and petroleum forced many researchers to develop and discover potential source of energy from plastics to overcome increasing power demand. The methods of pyrolysis had been created as a way of alternative processing and converting waste material into goods which can be used as a prospective source of electricity [7]. This particular study dealt with converting polypropylene plastic waste into useable fuel by infrared wave, finding out effect of temperatures on liquid yield and properties of yielded liquid.

## 2. MATERIALS AND EXPERIMENTAL PROCEDURES

For conducting the study an experimental setup has been fabricated. It was a fixed bed reactor made of stainless-steel.

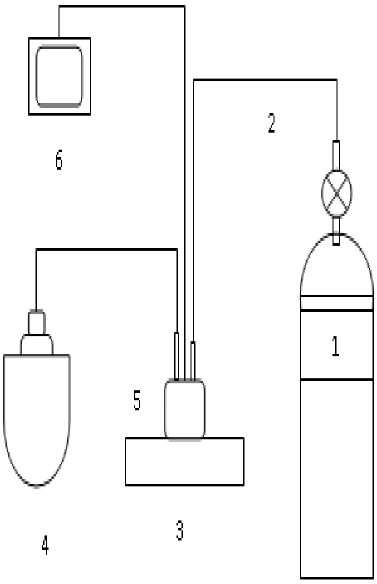
### 2.1 Materials

Recycled polypropylene plastic pellets were used in this study. Those were collected from local vendor. Plastic pellets were almost 1-2 mm in size. Impurities had been removed from the plastic pellets. Here, Fig. 1 shows the recycled polypropylene plastic pellets for pyrolysis process.

Fig. 1: Recycled polypropylene plastic pellets

### 2.2 Experimental Setup

Recycled polypropylene plastic pellets of 50 g were fed into the fixed bed reactor which was 7.62 cm in length and 3.69 cm in inner diameter. Then reactor was placed over an infrared cooker. There were three ports in the reactor. One was used for connecting the reactor with argon gas cylinder. The second one was used to connect the reactor with an ice bath. Finally, the third port was connected to the thermocouple for temperature reading. Above three, first two ports were open to the reactor which permitted the flow of argon and vapor respectively although the third port did not permit any leakage or transfer of vapor and gas. Then infrared cooker was switched on and studies were performed at different temperatures. Vapor and gas generated during thermal decomposition of plastics were condensed in an ice bath. Argon gas (carrier gas) was used to create an inert environment in the reactor and the flow was continuous throughout the process. Reaction time was 70 minutes and pyro-oil had been collected in the collector bottle. Here, Fig. 2 shows the schematic diagram of the experimental setup, Fig. 3 shows the image of the experimental setup and Fig. 4 shows the reactor measurements.




1. Argon gas cylinder
2. Copper tube
3. Infrared cooker
4. Ice bath
5. Stainless-steel reactor
6. Thermocouple and monitor

Fig. 2: Schematic of pyrolysis setup of waste plastic

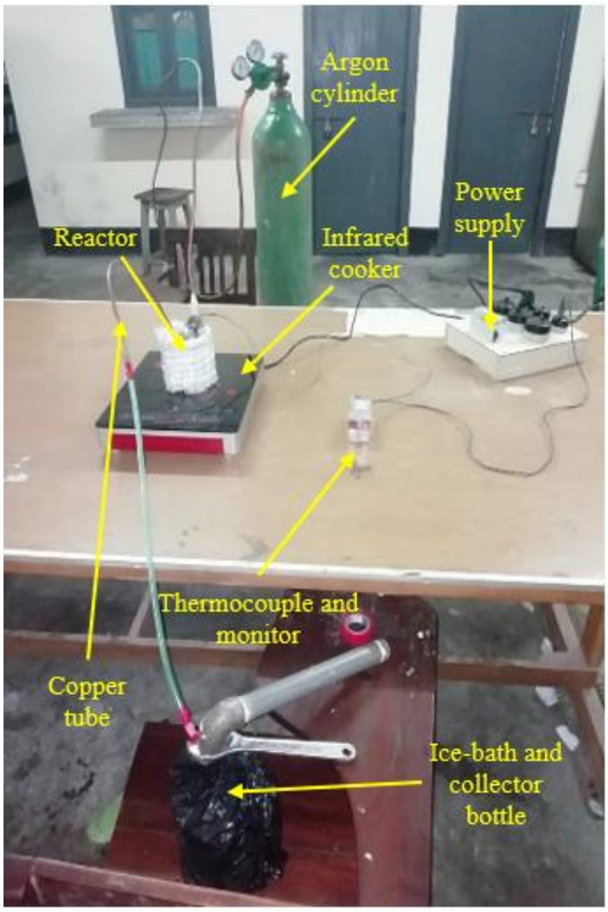



Fig. 3: Image of pyrolysis setup of waste plastic

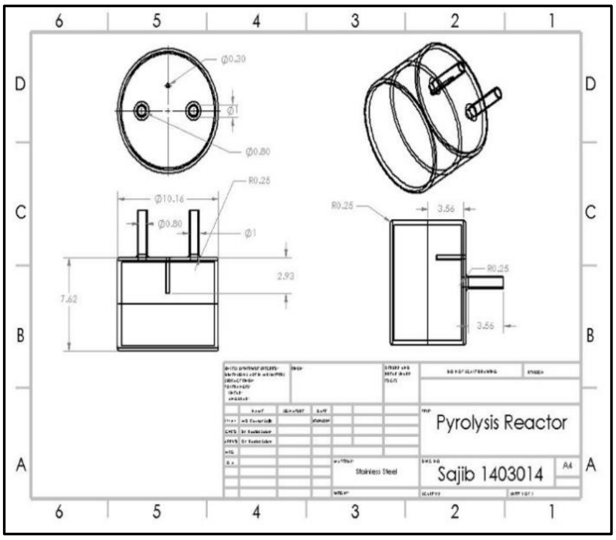



Fig. 4: Stainless-steel reactor measurements (in cm)

## 3. RESULTS AND DISCUSSION

In this particular study effect of temperature has been considered on liquid yield and conversion rate. Apart from these, physical properties of extracted pyro-oil have been found out. Comparison of different fuels have been demonstrated.

### 3.1 Effect of Temperature

Temperature effect on the liquid yield in PP pyrolysis is shown in Fig. 5. In this study, polypropylene plastic sample of 50g was used in all cases with 70 minutes reaction time. Pyro-oil of 21g has been extracted at 320°C. Conversion of liquid product was 42 wt.% in that case.

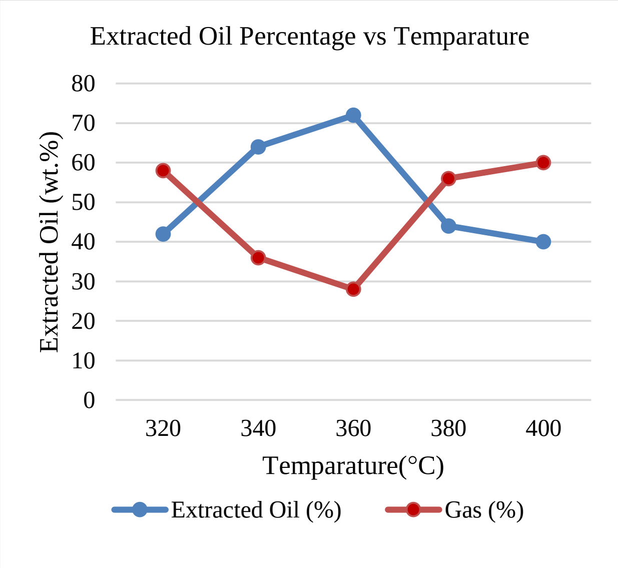



Fig.5: Extracted oil vs Temperature

In the second case, 32g or 64 wt.% pyro-oil was extracted at 340°C. Up to 360°C, conversion of liquid was in increasing manner and yielded the highest amount of pyro-oil that was 36g showing 72 wt.% liquid conversion efficiency although production of gas had decreased. This was because PP due to its branching framework, a readily degradable polyolefin. Another reason could be the greater percentage of tertiary carbon in polypropylene chains, which encourages the thermal cleavage of C-C bonds. When the temperature was further increased, conversion of pyro-oil had fallen down gradually but the production of gases started to increase. This was because the liquid products were eventually subjected to additional cracking in order to create gas at high temperatures [8]. In this study, production of solid residue was negligible. That was due to, reaction time is one of the important factors for producing oil, gas, char. when the residence period is long, secondary pyrolysis cracking starts which enhances the yield of gaseous product [9]. As there was a negligible amount of solid residue which presented an inverse relationship between liquid product and gaseous product.

### 3.2 Physical Properties

Various tests have been carried out to find the properties of liquid found in pyrolysis of PP plastics at 360°C. Calorific value, viscosity, flash point, fire point, specific gravity and density were determined. Table 1 shows the properties of liquid pyro-oil. Tests were conducted at 29.8 (°C).

Table 1: Properties of extracted pyro-oil at 360°C.

| | |
|---|---|
| Calorific value (MJ/kg) | 51.42 |
| Density (kg/m^3) | 714.5 |
| Flash point | 34°C |
| Fire point | 45°C |
| Dynamic viscosity (cP) | 14.6 |
| Kinematic viscosity (cSt) | 20.43 |
| Specific gravity | 0.7181 |

### 3.3 Comparison of different fuels with extracted pyro-oil

Here, Table 2 demonstrates the comparison of extracted pyro-oil with gasoline, kerosene and diesel.

Table 2: Comparison of different fuels properties with extracted pyro-oil [9].

| Properties | Gasoline | Kerosene | Diesel | PP pyrolysis liquid obtained |
|---|---|---|---|---|
| Density (kg/m^) | 743-751 (20-30°) | 760–767 (20-30°C) | 870-1000 | 714.5 (29.8°C) |
| Flash point (°C) | -46 | 38 | 38-58 | 34 |
| Calorific value (MJ/kg) | 47 | 46 | 45 | 51.42 |
| Viscosity (cP) | 0.41 (40°C) | 1.7 (40°C) | 3.35 (40°C) | 14.6 (29.8°C) |
| Specific gravity | 0.743-0.751 (20-30°) | 0.760–0.767 (20-30°C) | 0.870-1.0 | 0.7145 (29.8°C) |

It is clearly observed that the calorific value of extracted pyro-oil is greater than gasoline, kerosene and diesel. But specific gravity and density of pyro-oil are lower than other fuels in the table. Flash point of pyro-oil is close to kerosene.

### 3.4 Color of pyro-oil

Color of pyro-oil depends upon feeds and total experimental conditions. Oil color from single feed plastic pyrolysis is totally different from mixed feeds plastics. In this particular study polypropylene plastic was used and yielded liquid had a light yellowish color when it yielded at 320°C, and became deep yellowish at 340°C, 360°, 380°C and 400°C respectively. Here, Fig. 6 shows the sample of extracted pyro-oil at 360°C.

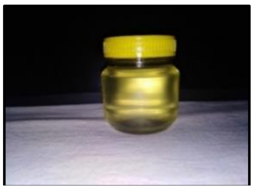


Fig. 6: Sample of extracted pyro-oil at 360°C

Apart from these, the samples which were taken at different temperatures are also given below. Which clearly indicates the variation of color and quantity based upon temperatures. Here, Fig. 7 shows the sample of collected oil at different temperatures.

(1) 320°C, 21 g

(2) 340°C, 32 g

(3) 380°C, 22 g

(4) 400°C, 20 g

Fig. 7: Samples of pyro-oil taken at different temperatures.

### 3.5 Economical and Engineering optimization

In this study maximum oil produced 36g or 72 wt.% from 50g plastic sample with 70 minutes reaction time. Moreover, 1kg ice was used to condense the vapor and gas in a single study. Heater was constantly heating the reactor at 2000-watt heating rate. So, an engineering optimization is needed to establish the validity of this study. Figure 8 shows the energy diagram of pyrolysis process.

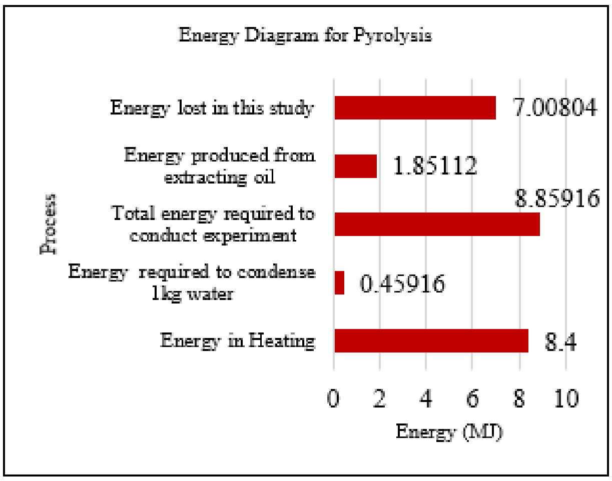



Fig. 8: Energy Diagram for Pyrolysis.

As it can be seen, around 7 MJ energy has been lost during the conversion of plastic waste to liquid oil. So, it is not feasible to conduct this type of conversion commercially. Rather waste heat energy should be used to produce pyro-oil without losing any energy.

## 4. CONCLUSION

There has been considerable environmental damage caused by plastic bags. It can take up to 1000 years for an individual plastic bag to decay. Animals like whales, turtles and birds die, mainly due to plastic in their environment, every year. Plastic bags have a negative impact not only on our natural habitat, but also have been found to lead to the death of many animals, especially as a result of the suffocation that they are eating. Pyrolysis is a method of transforming waste plastics into useable fuel. In this study polypropylene recycled plastics were used for pyrolysis process. Highest yield of liquid was 36g or 72 wt.% from 50g recycled polypropylene plastic at 360°C (2000W) for 70 minutes reaction time. Although the test was successful, it could be improved to enhance the process effectiveness. The following recommendations are suggested for further research to promote the commercialization of pyrolysis technique for waste plastic processing and to comprehend the pyrolysis method better:

-This experimental setup has only an ice bath to condense vapor. Vapor and gas produced can be initially cooled in a heat exchanger.

-It is observed during experiment that a big amount of gas and vapor were swept away by argon gas (carrier gas) through the ice bath collector which has caused low liquid oil collection. Hence, multistage ice bath cooling is recommended for trapping maximum amount of vapor and gas.

-Leakage in the experimental setup should be prevented.

-Heating surface of infrared cooker has a larger diameter than the reactor. Therefore, huge heat has been lost during operation. In commercial production of pyro-oil, the heating surface should be interactive with a reactor in such a manner to ensure no heat loss to environment

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