IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, S.Iss 07, 2022

Generation of Polly-fuel for Future

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Abstract:

In today's world, the extensive usage of plastic has surged due to rapid urbanization, population growth, and changes in human lifestyle. This escalating plastic consumption has led to a pressing need for effective solutions to manage the mounting plastic waste. Pyrolysis, categorized as a tertiary recycling method, presents a prospective remedy by disintegrating organic polymers under elevated temperatures without the presence of oxygen. This process produces synthetic gases, oils, and solid remnants as its outcomes. This experimental study aims to recycle plastic waste into fuel, introducing the concept of "Polyfuel," a fuel derived from plastics. Specifically, we focus on converting HDPE (High Density Polyethylene) waste into liquid fuel resembling diesel through catalytic cracking under thermal conditions in the temperature range of 400-450°C. The experimental setup consists of a 3-liter balloon flask serving as the reactor, with a beaker employed to collect the liquid fuel. The process employs a glass condenser to condense the vapors generated during the operation. Results show that at a reaction temperature of 400-450°C, 430 cc of gasoline was extracted from 800 grams of waste plastics. The collected Polyfuel was subjected to laboratory tests to assess its properties, and the analysis revealed that its characteristics closely match those of Diesel. Notably, the Density @150°C measures 0.7825 gm/ml, Moisture content is 200 mg/kg (ppm), and the Flash point is below 10°C.

Keywords: Polyfuel, Pyrolysis of waste plastic, Diesel, Flash Point.

1. Introduction

Plastics play a crucial role in our daily lives, finding applications in almost every industry owing to their versatile and practical characteristics, including lightness, flexibility, durability, cost-effectiveness, and rapid manufacturing capabilities. However, the extensive global production and consumption of plastics have led to a significant waste problem due to their non-biodegradable nature. Addressing plastic waste recycling has become a pressing global concern (Y. P. Chauhan et al., 2018).

In India, the generation of plastic waste has seen a staggering increase, with approximately 9.8 million tonnes produced in 2021 compared to 15,342 tonnes in 2013. This surge can be attributed to the prevalent use-and-dispose lifestyle that has become more widespread. A survey conducted in 2010-2011 by the Central Pollution Control Board (CPCB) revealed that Delhi generates the highest amount of plastic waste (690 tonnes/day), followed by Chennai (429 tonnes/day), Mumbai (408 tonnes/day), and Bengaluru (315 tonnes/day) (Y. P. Chauhan et al., 2015). Notably, around 70% of the total plastic waste generated comes from HDPE,

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LDPE, Polypropylene, and Polystyrene materials, primarily used for packaging. Sadly, only 60% of this waste is recycled, leaving the rest to contribute to pollution.

Disposal methods like landfilling and incineration have their drawbacks. The reduction of available land due to urbanization raises concerns about the future availability of space for landfilling plastic waste. Additionally, incineration releases harmful and toxic gases like CO, Cl_2, and HCl, while landfills lead to environmental pollution and infertility. Given these challenges, recycling plastic waste emerges as a necessary solution (Achilias, DS et al., 2004 and Ammar AS et al., 2008) to mitigate the environmental impact and manage the increasing waste problem effectively. Municipal plastic waste recycling rates lag behind industrial waste plastic recycling. However, in Maharashtra, some municipal corporations have taken steps towards recycling waste plastics by converting them into gasoline. Rudra Environmental Solution in India Ltd. has initiated the production of plastic recycling facilities to transform waste plastic into fuel. One such plant is operated by the Pune Municipal Corporation in the Dhankewadi ward, which impressively converts 9000 kg of plastic into 5400 liters of gasoline per month (Sonawane YB et al., 2014 and Sonawane YB et al., 2016).

Even though our expertise lies in civil engineering, we decided to venture into converting waste plastics into liquid fuel as a part of our commitment to environmental preservation. This research involves the outdoor pyrolysis of plastic waste in the absence of oxygen, aiming to obtain Polyfuel as the end result, utilizing laboratory apparatus.

2. Experimental work conducted

2.1. The Equipment used for pyrolysis process are as follows:

- 4neck, 3 litres balloon flask - 1nos.
- Condenser – 1 no's
- Connecting nozzle / bend of condenser – 2 no's
- Glass stopper for 3L neck flask – 3nos
- Flask/condenser holding MS pc. stand with bassests-1set
- Beaker stand- 1nos
- Asbestos cloth – 12”x12” -1pc
- Glass sample bottle – 2pc
- Teflon tape – 1pc
- Glass thermometer with holder – 1nos
- Water circulation pump – 1 nos.

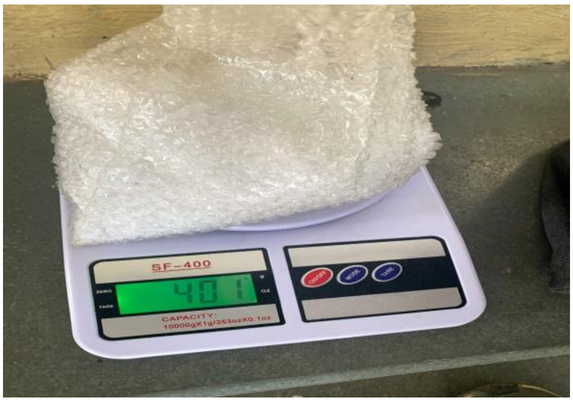

Figure 1. HDPE waste Granules

2.2. Materials

For this experiment, 800 grams of HDPE waste plastic granules were utilized.

2.3. Experimentation/pyrolysis setup

The entire experimental setup was constructed using borosilicate glass, which included components such as a glass condenser, beaker, balloon flask, and thermocouple. The HDPE waste plastic granules were placed in the reactor, and the temperature at which the plastic started melting was found to be 179°C. It took an average gas pressure (thermal power) of 25-30 minutes to reach this temperature. The pyrolysis process commenced at temperatures ranging from 350°C to 400°C.

To initiate the emission of gas, an LPG gas cylinder was used as a thermal power source under the balloon flask reactor. It took approximately 1 hour and 30 minutes to reach temperatures around 400°C to 410°C (Ali, MF et al., 2005). The fumes released from the beaker passed through the glass condenser, where water circulation facilitated condensation, turning the vapors into a liquid form. The resulting liquid fuel was collected in a separate beaker, while synthetic gases and char were treated accordingly (Jeong GH et al., 2006).

The approximate percentage composition of the end products was determined as follows: Polyfuel accounted for 60-65%, synthetic gases for 10-15%, and char contained 5% carbon content and hydrocarbon. The remaining gases in the balloon flask after the process could be treated and utilized in the construction of bituminous roads. Additionally, the syngas, being flammable in nature, could be collected and used for the boiler's incineration process (Sarwar J et al., 2015).

To assess the characteristics of the produced Polyfuel, various parameters were measured, including the gross calorific value (10970 kcal/kg), density at 150°C (0.7825 gm/ml), moisture content (200 mg/kg), and flashpoint (<100°C), conducted by Geo Chem Laboratories PVT.LTD.

3. Result & Discussion

Pyrolysis is a chemical reaction process that initiates the melting of HDPE plastic at temperatures ranging from 150°C to 200°C, which takes approximately 25-30 minutes. The de-polymerization of HDPE occurs between 380°C to 430°C, producing hot hydrocarbon vapors and synthetic gas. To facilitate the condensation and cooling of these gases into liquid form, a condenser is connected to the reactor (Raja, A et al., 2011).

Upon testing the extracted sample, we observed its highly flammable nature. To further assess the characteristics of the Polyfuel sample, we sent it to GeoChem Laboratories PVT. LTD. for analysis. The reports received from the laboratory indicate that the extracted Polyfuel sample is comparable and shows potential as a viable alternative to Diesel fuel.

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Pyrolysis is a chemical process that causes HDPE plastic to melt within a temperature range of 150°C to 200°C, and this typically takes around 25-30 minutes. As the temperature rises further, between 380°C to 430°C, the HDPE undergoes de-polymerization, resulting in the generation of hot hydrocarbon vapors and synthetic gas. To condense and cool these gases into a liquid state, a condenser is connected to the reactor (Raja, A et al., 2011).

After conducting tests on the extracted sample, we observed its highly flammable nature. For a more comprehensive assessment of the Polyfuel sample's characteristics, we sent it to GeoChem Laboratories PVT. LTD. for analysis. The laboratory reports confirm that the extracted Polyfuel sample is comparable and demonstrates potential as a feasible alternative to Diesel fuel.

3.1. Physical Testing

During the process, the ultimate result was the extraction of the final liquid fuel, referred to as polyfuel. We observed that the collected polyfuel exhibited a clear liquid form (Fig. 4), resembling the characteristics of Diesel. To assess its flammability, we conducted tests on the extracted fuel, and the results indicated that it is highly flammable (Fig. 5).

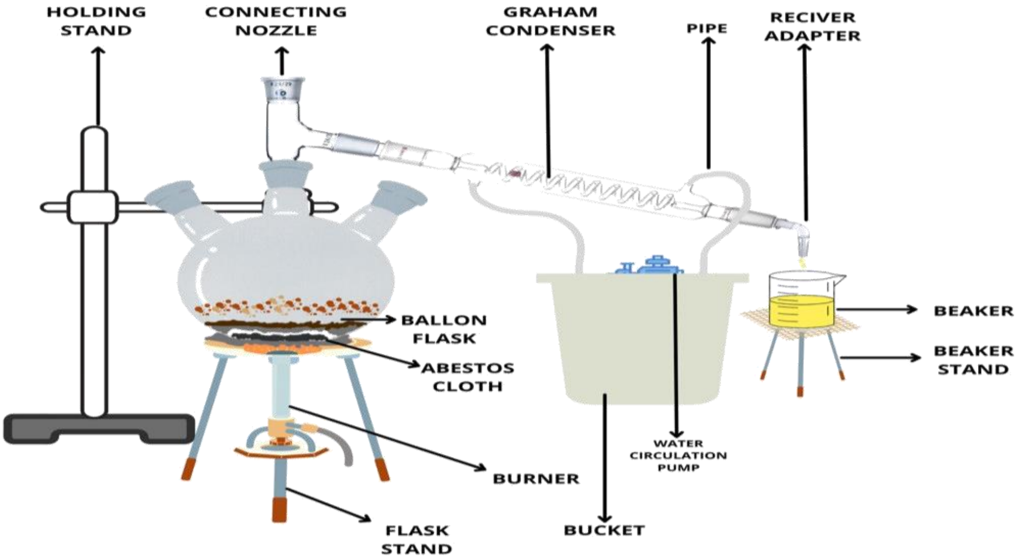

Figure 2. *The schematic setup*

Figure 3. *The model setup*

Figure 4. *Flammability Test*

Figure 5. *Extracted Sample*

3.2. Analytical Testing:

The extracted Polyfuel oil sample underwent further analysis in a testing laboratory. Based on the reports received, we observed that the characteristics of the Polyfuel oil match those of diesel. This finding indicates a successful energy recovery process. This aligns with the principles of the 4R's: Reduce, Reuse, Recycle, and Recovery (Osueke CO et al., 2011).

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Table 1. *Comparing pyrolysis oil (polyfuel) to diesel*

Sr. No	Fuel	Gross Calorific Value (kcal/kg)	Density @ 15 ^{O}C (gm/ml)	Flash Point (^{O}C)	Moisture Content (mg/kg) ppm	Price 450 ml (₹)
1	Polyfuel	10970	0.7825	<10	200	34.46
2	Diesel	11000	0.8750	52	100-150	47.20
3	Petrol	11110	0.7236	-43	N.R	54.98
4	Kerosene	11100	0.8875	38	N.R	23.5

(Khanna S et.al, 2013; Kumar S et.al, 2011; Miskolczi N et.al, 2009)

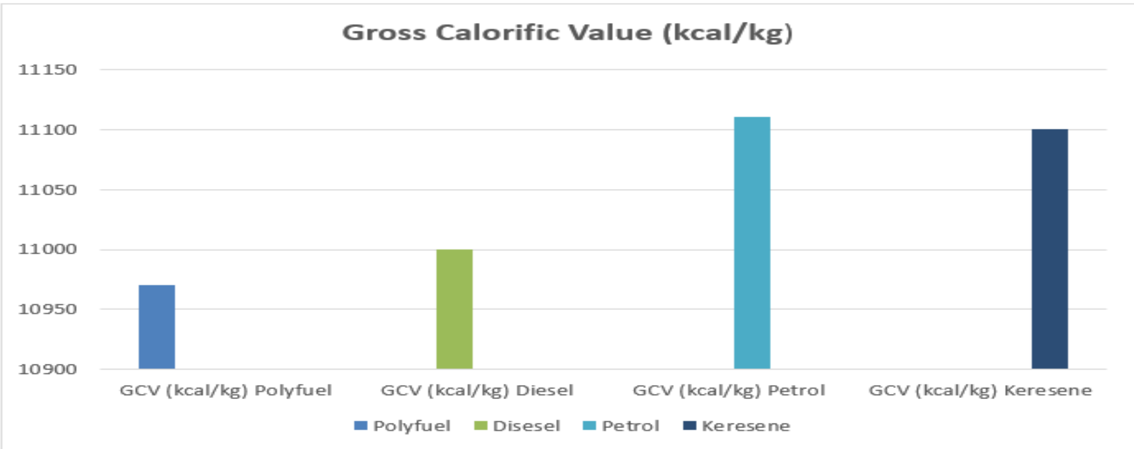

Figure 6. *Gross calorific value*

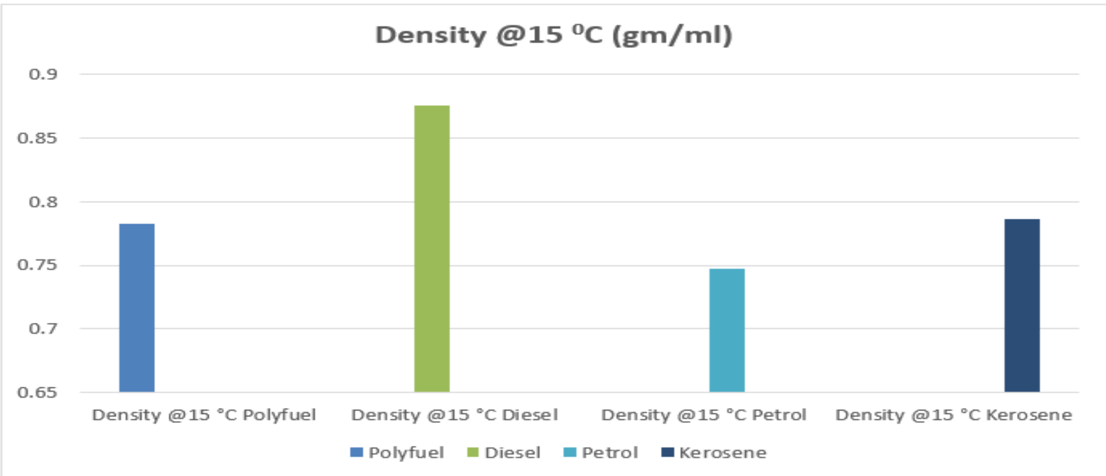

Figure 7. *Density at 15ºC*

IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

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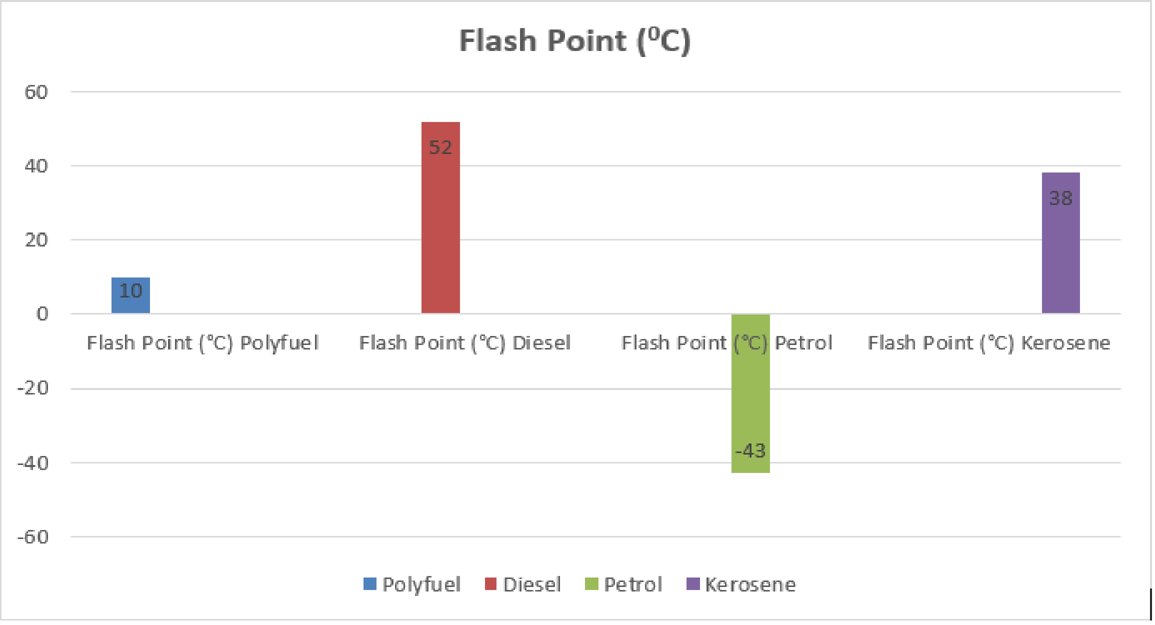

Figure 8. *Flash point*

Table 2: *Chemical Analysis Parameters*

Sr. No	Test	Method/ Technique	Result	Unit of Mesure
1	Gross Calorific Value	ASTM D- 4809- 18	10970	Kcal/kg
2	Flash Point	IP – 170- 13	<10	^{o}C
3	Desnity @15 ^{0}C	ASTM D- 4052- 18	0.7825	gm/ml
4	Moisture	ASTM E 203- 16	200	Mg/kg (ppm)

3.3. Time - Temperature Behavior

The reactor's time-temperature behavior, depicted in Figure 6, shows that the initial temperature reading is 28°C. After 20 minutes, the reactor temperature reaches 121°C, causing the HDPE waste inside to start melting. Once the temperature surpasses 179°C, the recycling HDPE fully melts. As the temperature approaches approximately 380-430°C, the recycling HDPE initiates the process of depolymerization. At around 400°C, the depolymerization leads to the formation of hydrocarbon vapor and synthetic gas.

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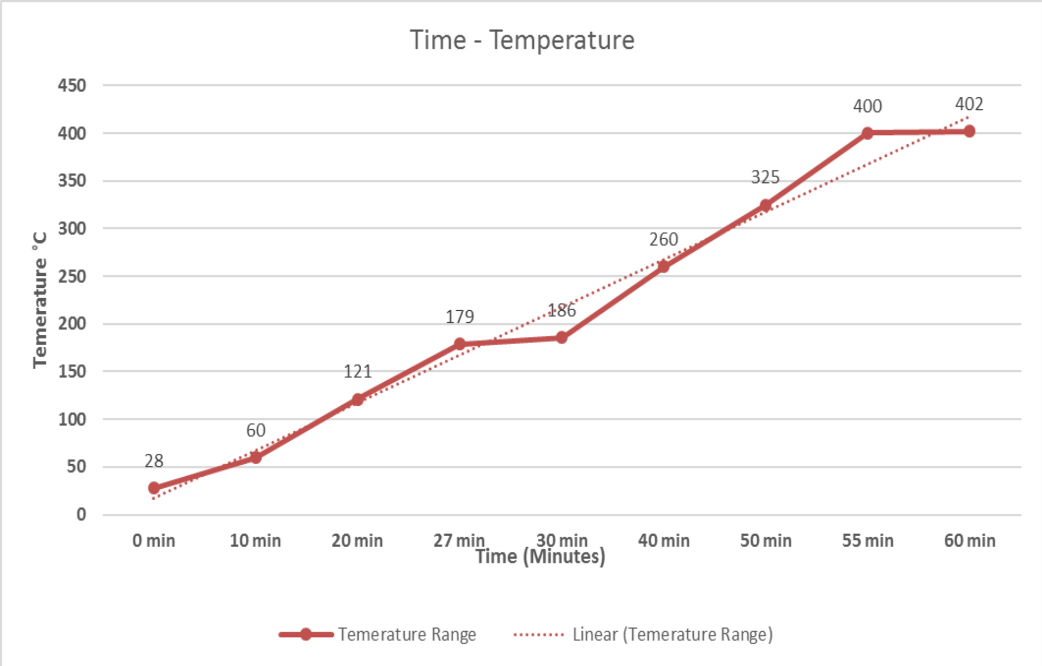

Figure 6. *Time temperature graph for pyrolysis process*

3.4. Residue Generation

At the conclusion of this process, a residue known as Black Char constitutes approximately 5-7%. This Black Char residue possesses substantial strength and bonding properties, making it suitable for road construction activities. It finds application in both rigid and flexible pavement construction. In rigid pavement, the residue is used for crack and gap filling purposes. Additionally, the syngas produced is highly combustible and serves as a valuable fuel source for internal combustion engines and boilers. Furthermore, it can be utilized as an industrial feedstock in various catalytic processes (Tiwari DC et al., 2009).

4. Conclusion

The issue of recycling plastic waste and the limited availability of liquid fuel in emerging nations such as India, Brazil, Argentina, and Guyana can be efficiently tackled by transforming discarded plastics into Polyfuel. The pyrolysis of high-density polyethylene (HDPE) waste plastics demonstrates a direct and economical procedure. By adjusting process factors like temperature, pressure, and making good investments, the yield of the product can be increased. The fuel derived from this study has been found to be comparable to regular diesel fuel used in automobiles. Therefore, it can be inferred that "Polyfuel" holds promise as a future alternative fuel that could alleviate various issues. Moreover, since this process generates no waste, it is referred to as a zero discharge process.

5. Acknowledgements

We extend our sincere gratitude to Mr. Sharad Nikam, the Founder of Nikam Scientific Company, for his valuable support in completing our project. Additionally, we would like to express our thanks to St. John College of Engineering and Management, Palghar, for providing us with all the necessary resources throughout the project.

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