

LIQUID FUEL PRODUCTION FROM WASTE PLASTIC USING SMALL-SCALE PYROLYSIS PROCESS

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ABSTRACT

Plastic waste accumulation is a big problem for our environment because it does not degrade naturally. In this project work, we have studied the thermal decomposition of waste Low-Density Polyethylene (LDPE) plastic under controlled heating to get liquid alternative fuel. For this experiment, we set up a small batch reactor using simple and low-cost materials, and added a water-cooling loop for vapor condensation. In our test runs, we took 8.0 kg of washed and shredded plastic pieces in the container. the heating process took around 4.5 to 5 hours, and we got about 4.20 to 4.65 liters of liquid fuel oil along with some solid carbon char at the bottom. During open flame testing, the collected fuel sample burned easily. This project indicates that we can manage domestic waste plastic effectively by converting it into liquid fuel using a simple pyrolysis setup.

1. INTRODUCTION

Every day, large quantities of plastic materials like bags, containers, and packaging sheets are used because they are cheap and easy to handle. But disposing of this post-consumer plastic waste has become a serious environmental issue. Most of the plastic waste goes to landfills or is burned openly, which creates harmful gases and soil pollution. Therefore, we need better recycling methods to handle this problem locally.

Pyrolysis is a chemical decomposition method where we heat the polymer material at high temperatures in the complete absence of oxygen. Because there is no air inside, the plastic does not catch fire; instead, its long chemical chains break down into shorter liquid and gaseous hydrocarbon components. In our project work, we planned and built a small-scale batch pyrolyzer setup to test how much liquid fuel we can obtain from domestic LDPE waste plastic without using high-cost commercial machinery.

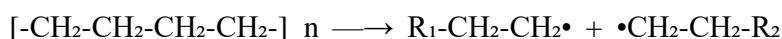
2. CHEMICAL REACTION AND CRACKING MECHANISM

Low-Density Polyethylene (LDPE) is made of long carbon chain structures represented as $(-\text{CH}_2-\text{CH}_2)_n$. When we supply continuous heat inside the tightly sealed reactor chamber, the polymer molecules absorb the thermal energy. This high temperature causes homolytic scission, meaning the strong carbon-carbon bonds start breaking down randomly into smaller reactive pieces called free radicals.

The standard steps of chemical transformation during the thermal breakdown are given below:

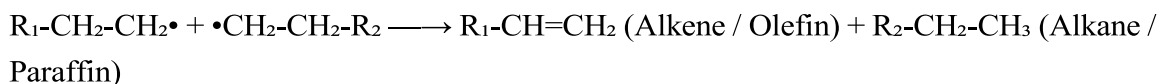
Step 1: Initiation (Chain Scission)

The long LDPE plastic molecule breaks into active, shorter radical chains due to heat:



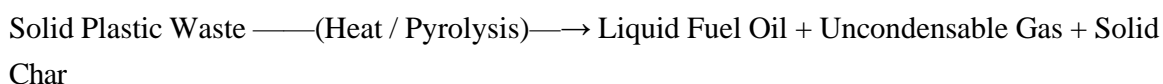
Step 2: Radical Stabilization (Product Formation)

The unstable radicals exchange hydrogen atoms internally and become stable molecules, forming liquid alkanes and alkenes:



Step 3: Overall Final Output Summary

The collective change inside the batch container can be simply written as:



3. EXPERIMENTAL MATERIALS AND SETUP DESIGN

3.1 Description of the Fabricated Setup

Our experimental setup was completely built using low-cost and easily available items. The main cracking container is a heavy metal vessel with a capacity of nearly 18 liters. The top cover plate of this container was tightly locked with leak-proof seals to avoid any oxygen ingress. From the top of the vessel, a metal pipe line was connected to guide the vapors out. This pipe was connected to a cooling water loop where cold water was regularly circulated over the tube line to condense the hot chemical vapors. The whole reactor setup was built on a firm brick foundation, and an industrial LPG gas burner was used underneath to heat the vessel.



Figure 1: Simple fabricated batch reactor setup built on brick foundation.



Figure 2: Custom water-cooled condensation pipe arrangement used in our experiment.

3.2 Experimental Run Procedure

We collected the post-consumer LDPE waste scraps from nearby residential areas. First, we washed all the collected plastic with clean water to remove dust or organic impurities, and dried it fully in the sun. Then, we cut the clean plastic sheets into small pieces (approx. 2-3 cm size) so that it could fit tightly inside the metal container. For every individual run, we took exactly 8.0 kg of this processed plastic material.

After closing the top lid tightly, we turned on the LPG burner to heat up the reactor chamber. When the chamber reached high temperatures, the plastic melted and started turning into gaseous vapors. These vapors traveled through the upper delivery pipe into our water-cooled condensation line. Inside the condenser, the gaseous vapors cooled down rapidly and turned into a liquid bio-fuel, which we collected inside a clear measuring jar. The remaining light gases that did not condense were allowed to pass out safely through an exhaust valve, where we tested their flammability using a matchstick.



Figure 3: Collected sample of the condensed liquid alternative fuel.



Figure 4: Live flammability check of the non-condensable gas at the exhaust point.

4. OBSERVATIONS AND RESULTS

To confirm that our custom-made process works consistently, we carried out three separate experimental runs (Run 1, Run 2, and Run 3) using the same quantity of raw plastic feedstock. We recorded the total process time, collected liquid oil volume, and left-over black char mass for all the runs.

Run Number	Plastic Weight (kg)	Time Taken	Liquid Fuel (L)	Char Residue (kg)
Run 1	8.0 kg	5 hours 10 minutes	4.20 L	2.2 kg
Run 2	8.0 kg	4 hours 40 minutes	4.65 L	1.9 kg
Run 3	8.0 kg	4 hours 55 minutes	4.38 L	2.0 kg

The observation data shows that our small setup gave highly stable output in all three trials. The

liquid fuel extraction stayed consistently between 4.20 liters and 4.65 liters from 8 kg of plastic feed. The solid black char collected from the bottom of the reactor was around 1.9 kg to 2.2 kg, which represents the fixed carbon residue. The remaining weight fraction went out as non-condensable light synthesis gas, which caught fire immediately during our open-flame matchstick checks (as shown in Figure 4), proving it is a high-energy combustible gas blend.

5. CONCLUSION

Our practical project work shows that small-scale thermal pyrolysis is a successful and practical way to convert post-consumer waste plastic into alternative liquid fuel oil. Even though the cracking reactor and cooling tube line were made manually from everyday low-cost components, we safely achieved steady thermal cracking and liquid fuel extraction. The isolated fuel product has clean burning properties, showing great potential to be used as heating oil or industrial burner fuel. This decentralized recycling method can help a lot in reducing municipal plastic load right at the local source points.

6. REFERENCES

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