International Journal of Science, Environment and Technology, Vol. 5, No 3, 2016, 1421 – 1425

ISSN 2278-3687 (O)
2277-663X (P)

# HIGH DENSITY POLYETHYLENE WASTE TREATMENT BY USING CATALYTIC PYROLYSIS TO RECOVER LIQUID FUEL

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**Abstract:** In India, 60 % plastic waste is recycled and 40 % remains untreated, so there is a need to manage this untreated plastic waste to solve environmental problems occurred due to plastic waste pollution. There are different methods for recovering chemicals and hydrocarbon fuel from plastic waste like solvent extraction, liquefaction, pyrolysis, catalytic cracking etc. High density polyethylene is one of the major components in household plastic waste which can be easily recovered by pyrolysis method without any harm to environment.
In present work, lab scale experimental set up was designed for pyrolysis process. HDPE milk carrybags were used as a raw material. Temperature was optimized for maximum liquid fuel production. Reactions were carried out at $450^0$C without catalyst, with 5 wt % alumina and by using 5 wt % silica-alumina in 7:3 and 8:2 proportions. The Yield of liquid fuel obtained without catalyst was observed 73%. By using silica it was observed about 54%, with alumina, yield obtained was 68 % and by using 5% silica-alumina (7:3) and (8:2), yield enhanced upto 87% and 85% respectively.
Liquid fuels obtained without and with catalyst were tested for density and calorific value. Calorific values of liquid fuel obtained with alumina and silica-alumina catalyst have been enhanced upto 43000 KJ/Kg as compared to without catalyst i.e. 41000 KJ/Kg.
**Keywords:** High Density Polyethylene waste, catalytic pyrolysis, liquid fuel.

## Introduction

In India, plastic waste accounts to about 10 thousand tons per day [1]. At these alarming levels of waste generation, India needs to set up facilities for recycling and disposing the waste. If segregation and recycling of these plastic waste not done properly, it increases load on landfill sites because of their non-biodegradable nature and ultimately causes environmental problems [2] like air, soil and ground water pollution as well as loss of marine biodiversity.

About 78 wt% of household plastic waste is of thermoplastic type which includes mainly High Density Polyethylene, Low Density Polyethylene, Polypropylene and Polystyrene [3]. These types are used for making carry bags, glasses, plastic bottles and milk and food containers etc. Mechanical recycling and other methods require high transportation and

*Received May 12, 2016 * Published June 2, 2016 * www.ijset.net*

treatment cost. In pyrolysis method, the waste plastics are thermally or catalytically degraded into gases and oils, which can be used as resources in fuels or chemicals [4]. Pyrolysis of HDPE has been studied without catalyst by some researchers [5,6]. Many researchers also studied different catalysts in pyrolysis process for enhancing yield of product [7,8,9,10,11]. Though pyrolysis process converts waste plastic into valuable product, the total efficiency in terms of cost and energy cannot be achieved. By using catalyst, we can save the electricity consumption and enhance quantity and quality of liquid fuel. Present research work focuses on studying catalytic effect of silica and alumina separately and in combination.

**Materials and Methodology:**

**Materials:** Feedstock used for the process was HDPE milk carrybags obtained from household sources. The shredding, washing and drying of material was done manually. 100 grams of HDPE waste material was used for each experiment.

**Catalyst preparation:**

Silica powder, alumina powder and mixture of silica-alumina with different ratios (i.e. 7:3 and 8:2) were used as catalyst. Grinding of Silica, Alumina and mixture of Silica- Alumina was done with the help of ball mill for 3 hrs with the speed of 100 rpm. 5 grams of catalyst was used in the reaction for 100 grams of HDPE waste.

**Pyrolysis set up:** The whole set up consisted of 500 ml capacity round bottom flask made from borosilicate glass, nitrogen inlet, thermocouple, temperature indicator, energy meter, condenser, collection flask and gas bladder. Shredded plastic waste material was fed into a reactor for polymer cracking. The heating mantle with 1000 ml capacity was used as a source of heating. Before starting reaction, nitrogen gas with flow rate of 50 ml/min was purged for 2 minutes into a reactor to create an inert atmosphere.

Preliminary experiments were carried out to optimize parameters like temperature and percent catalyst. Maximum yield for HDPE was obtained at the temperature range of 430-470$^0$C and with 5 wt % catalyst. So experiments were carried out at maximum temperature range of about 430-470$^0$C without catalyst and by using 5% silica, 5% alumina and 5% mixture of silica-alumina with wt. ratio of 7:3 and 8:2. Electricity consumption was recorded for reactions without catalyst and by using catalyst.

The vapours coming out after melting of material were passed through condenser and liquid obtained was collected in collection flask. The waxy residue and uncondensed hydrocarbon gases were generated as byproducts. Uncondensed gases were collected in gas bladder and leached in cold water bath. Density of liquid fuel was determined with the help of specific gravity bottle. Determination of calorific value was done with the help of Bomb calorimeter of make-Rico Scientific and model- RSBT-6.

**Results and Discussion**

In the pyrolysis reaction of HDPE waste, liquid fuel obtained without catalyst by using silica, alumina and mixture of silica-alumina (SA) with different ratios i.e. 7:3 and 8:2 liquid fuel is given in the following table.

**Table 1: Liquid fuel obtained by pyrolysis of HDPE waste**

| Sr. No. | Material (100g) | Liquid fuel in ml | Density | Liquid fuel (%) |
|---|---|---|---|---|
| 1 | HDPE without catalyst | 96 ml | 0.757 | 72.66 |
| 2 | HDPE with 5% silica | 72 ml | 0.759 | 54.64 |
| 3 | HDPE with 5% alumina | 90 ml | 0.757 | 68.10 |
| 4 | HDPE with 5% SA (7:3) | 115 ml | 0.760 | 87.34 |
| 5 | HDPE with 5 % SA (8:2) | 112 ml | 0.760 | 85.07 |

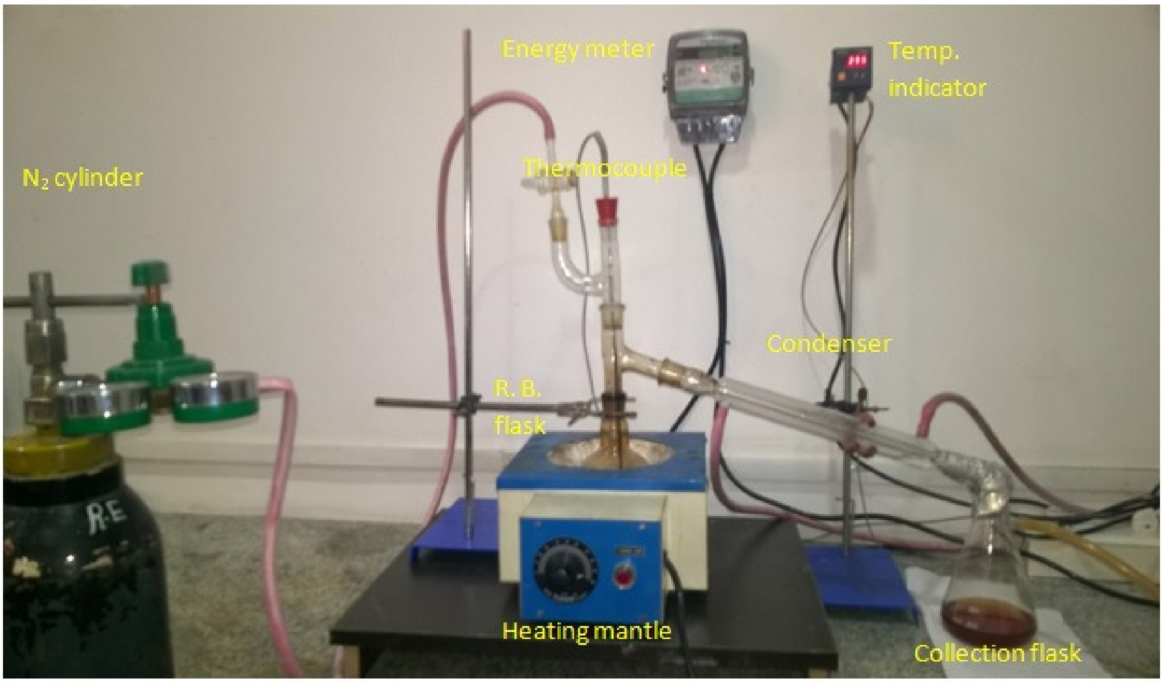


**Figure 1. Pyrolysis Experimental set up**

It was observed that by using silica-alumina catalyst, electricity consumption reduced from 0.5 KWh to 0.3 KWh as reaction time reduced from 2.5 hrs to 2 hrs. The percent yield obtained by using single catalyst as silica or alumina is less as compared to that of without catalyst. But by using mixture of silica-alumina the percent liquid fuel enhanced from 72 % to 85-87 %. As compared to 8:2 ratio of silica-alumina, yield obtained was high at 7:3 ratios.

**Table 2: Calorific values of Liquid fuel obtained**

| Sr. No. | Material | Calorific values (KJ/Kg) |
|---|---|---|
| 1 | HDPE without catalyst | 40614 |
| 2 | HDPE with 5% silica | 39870 |
| 3 | HDPE with 5% alumina | 42335 |
| 4 | HDPE with 5% silica-alumina with ratio 7:3 | 43800 |
| 5 | HDPE with 5 % silica-alumina with ratio 8:2 | 43648 |

Calorific values obtained by using different catalysts were compared and it was observed that without catalyst the calorific value of liquid fuel is 40614KJ/Kg while by using only silica it has reduced to 39870 KJ/Kg and by using only alumina, it increased upto 42335 KJ/Kg. The maximum calorific value obtained was with 5% silica-alumina with ratio of 7:3, i.e. 43800 KJ/Kg.

## Conclusion

Pyrolysis experimental set up has been successfully installed which converted HDPE waste into liquid fuel. By using 5 % silica-alumina mixture as a catalyst enhanced liquid fuel percent from 73 % to 85-87 %. The obtained liquid fuel by using silica-alumina has calorific value in the range of 43500-43800 KJ/Kg. The calorific value of diesel is in the range of 45000 KJ/Kg, so calorific values of liquid fuel obtained by pyrolysis with and without catalyst shows its applications in different industrial sectors for running boilers and diesel generators etc. The obtained liquid fuel can be also used as furnace oil.

## Acknowledgement

Authors acknowledge Director, College of Engineering, Pune for his constant encouragement for pursuing innovative research work, TEQIP for providing fellowship to research student.

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