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Catalytic and Non Catalytic Reactions of Plastic Waste using a Batch Pyrolysis Method for the Generation of Low-Emission Fuel

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Abstract:

Plastic manufacturing and usage have been increasing world-wide. No alternative materials are introduced effectively till date for plastics. Disposal of plastics caused severe chronic problems to the environment and also to the living beings. Even though many methods were employed to dispose the plastics, pyrolysis is the method of choice for converting waste plastic into low-emissive hydrocarbon fuel. Hence, the present research was aimed to investigate the conversion of waste plastics like high density polyethylene (HDPE), low density polyethylene (LDPE) and polypropylene into fuel gases and oils using pyrolysis method. In this method, thermal degradation of the waste plastics was carried out up to 400 C in the presence of a catalyst, activated carbon. Similar experimental set up was carried out without catalyst. Increased fuel yield was obtained for the reaction process in the presence of catalyst than in the absence of catalyst. Activated carbon used as catalyst in the pyrolysis process influenced the yield and composition of the fuel. The characteristics values of fuel from the reaction in the presence of activated carbon are lower than the reaction in the absence of activated carbon indicating that the generated fuel is safety.

Keywords: *Plastic, HDPE, LDPE, Polypropylene, Thermal degradation, catalytic pyrolysis*

1.Introduction

Eco-friendly fuels alternative to fossil fuels are required world-wide to compensate the demand of petroleum products and other greenhouse gases [1]. Alternatives to the existing fuels were reported to be compensated by the significant application of waste recycling process [2]. Plastics, metals, papers, organic matters, and other trace elements are highly used in the waste recycling process. Among these waste materials, plastics were considered most indispensable materials world-wide. Materials made of plastics are not easily biodegradable and considered very difficult to dispose like land filling and incineration [3].

Plastic usage has been increasing for the last few decades because of its properties like flexible, durable, light weight, corrosive resistant, and compatible. It is used in different types of industries like automobiles, food and beverages, textiles, medical, pharmaceuticals and electronics. Based on the types of products manufactured, plastic and its types were found varied [4]. High-density polyethylene (HDPE), linear low-density polyethylene (LLDPE), and low-density polyethylene (LDPE) are the types or classes of

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plastics synthesized from ethylene polymerization process [5]. Plastics prepared from such classes are subjected to solid waste management methods. The method signifies the conversion of plastics in any form to a useful resource. Recycling, incineration, and thermal cracking are the methods described under the waste management systems [6].

Thermal cracking studies on polyethylene [7], polystyrene [8], and polypropylene [9] were done by the process called pyrolysis. In pyrolysis the waste plastics are converted into fuel oil and other essential gases [10]. Pyrolysis is a thermochemical decomposition of synthetic materials to produce fuels at elevated temperatures (300°C to 500°C) in the absence of oxygen [11]. Natural zeolite, activated carbon and calcium oxide was used as catalyst to reduce the operating elevated temperature in the process [12].

The present research was thus aimed to investigate the conversion of waste plastics like HDPE, LDPE and polypropylene into fuel gases or oils using pyrolysis under controlled experimental setup. The work is framed with an objective of converting the plastic residues into alternate fuel energy resource to the environment.

2.Materials and Methods

Waste plastic materials of HDPE, LDPE and polypropylene were collected from the municipal waste disposal department, Coimbatore, Tamil Nadu, India. Collected plastics were pre-processed by cleaning and rinsing with water to remove any solid debris. All the samples were dried and made into pieces (8cm x 8cm). Activated carbon was commercially procured from a local supplier.

Pyrolysis process

Plastic pyrolysis process was carried out on a laboratory scale reactor. The reactor comprises an empty round bottom borosil glass flask (1000 mL), a condenser and a heating mantle. Each type of pre-processed plastics (900g) was loaded into the flask with 300g of activated carbon (as catalyst bed). Flask was placed onto the heating mantle and temperature was maintained between 100°C to 200°C. Condenser was connected to the reactor and ensured for the circulation of cooling water in the condenser throughout the experiment. During the process, the pyrolytic liquid products were collected from the lower part of the condenser. The collected products were refluxed and distilled. Three fractions were collected for each trial of product. Similar experimental setup without catalyst was done as a control.

In Table-1, the distillation temperature used in the process is presented for all three plastic samples. Three temperature trials were carried out for each sample.

Table-1: Distillation temperature (°C)

Samples	Trials		
	Trial 1 (°C)	Trial 2 (°C)	Trial 3 (°C)
LDPE	370	375	373
HDPE	380	389	380
PP	400	402	398

The melting point of the samples during the pyrolysis process for each trial were recorded periodically and presented in Table-2.

Table-2: Melting point (°C)

Samples	Trials		
	Trial 1 (°C)	Trial 2 (°C)	Trial 3 (°C)
LDPE	120	123	125
HDPE	130	131	140
PP	160	164	166

Analysis of the pyrolytic products

The yield of the pyrolytic products was measured for its density using IP131/57 standards. All the other contents were measured using ASTM standard methods. Flash point (ASTM D 93), fire point (ASTM D 93), carbon residue (ASTM D 189-

65), ash content (ASTM D 48) and sulphur content (ASTM D 129).

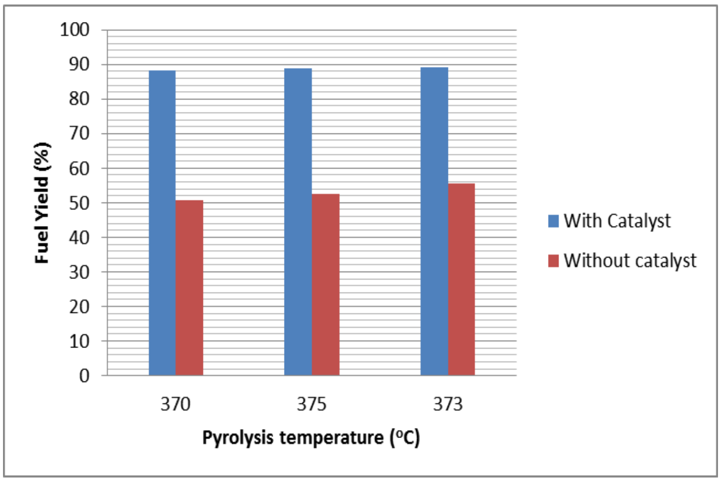
3.Results and Discussion

Conversion of waste plastics into a liquid fuel hydrocarbon was investigated at three different pyrolysis temperature for each types of plastics like low and high density polyethylene (LDPE and HDPE), and polypropylene (PP). Simple thermal degradation was used to melt the plastics at temperature ranging from 100 to 200 °C. Vapour condensation form the melted plastics produced the liquid fuel product. The effect of reaction on quality and yield of the product were investigated. The results of pyrolysis process indicated higher yield percentage of fuel in the presence of catalyst than in the absence of catalyst. The catalyst has influenced the yield and the composition of the fuel yield.

The pyrolysis product yield at different experimental temperatures is presented in Figure-1, 2 and 3 for all three types of plastic waste used in the study. Fuel yield from LDPE, HDPE and PP waste increased slightly when the temperature was increasing. The increase is due to the pyrolysis reaction rate which was reported to be faster at higher temperatures. However, thermal decomposition of LDPE, HDPE and PP plastic waste was carried out only at high temperatures. Since, no much temperature difference was set for the pyrolysis process during this experiment, the fuel yield was found to be high at all the three set temperatures.

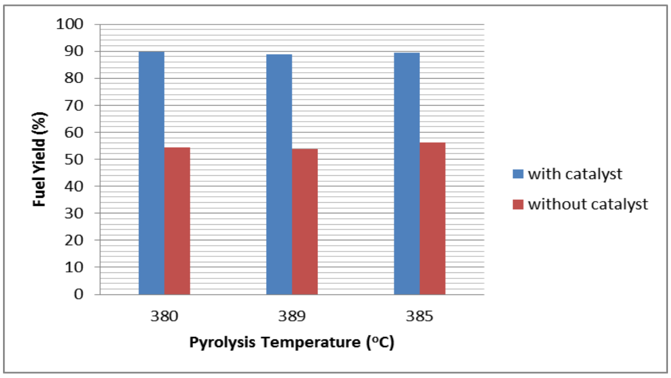
In Fig-1, conversion of LDPE plastic waste into a pyrolytic product with and without catalyst is presented. Fuel yield was found more when the process was experimented with activated carbon (catalyst), when compared to the experiments without catalyst. In all the three experimental temperatures (370°C, 375°C and 373°C), the difference in fuel yield between the process with and without catalyst was observed. At 370°C, the fuel yield using activated carbon showed 88.3%, while experiment without catalyst produced 50.8%. Similarly, at 375°C and 373°C the fuel yield with catalyst was 88.9% and 89.1% respectively; without catalyst the yield was only 52.5% and 55.6% respectively.

Fig-1: Fuel yield (%) from LDPE at different pyrolysis temperatures (With and without catalyst)



HDPE plastic waste conversion into fuel product with and without activated carbon is illustrated in Fig-2. At 380°C, the fuel yield using activated carbon showed 89.8%, while experiment without catalyst produced 54.5%. Similarly, at 389°C and 385°C the fuel yield with catalyst was 89.0% and 89.6% respectively; without catalyst the yield was only 53.8% and 56.2% respectively.

Fig-2: Fuel yield (%) from HDPE at different pyrolysis temperatures (With and without catalyst)



Polypropylene based plastic waste was converted into liquid fuel with and without the presence of catalyst (Fig-3). When compared to the

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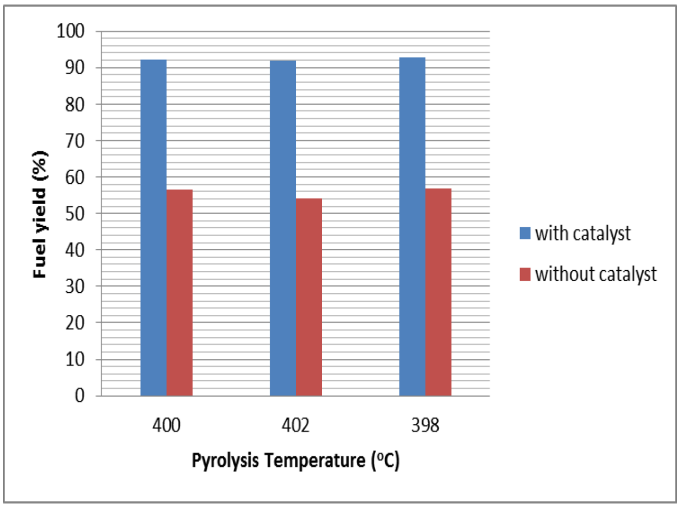
experimental studies of LDPE and HDPE, slightly higher fuel yield was observed during the conversion of PP plastics. In the presence of catalyst, 92.3% of fuel yield was obtained at 400°C, while the process without catalyst exhibited generated only 56.4%. At 402°C and 398°C the fuel yield with catalyst was 91.8% and 92.8% respectively; without catalyst the yield was only 54.2% and 56.8% respectively.

Fig-3: Fuel yield (%) from PP at different pyrolysis temperatures (With and without catalyst)



Different parameters analysed during the yield of pyrolysis product from LDPE, HDPE and PP plastic wastes were described in Table-3, 4 and 5 respectively. Parameters like density, flash point, fire point, and sulphur content during each experiment was analysed along with the fuel yield.

Table-3: Parameters analysed for pyrolysis products of LDPE (With and without catalyst)

Parameters	Pyrolysis Temperature (°C)					
	Catalytic Reaction (°C)			Non-catalytic Reaction (°C)		
	370	375	373	370	375	373
Fuel density (g/ml)	0.77	0.78	0.78	0.81	0.82	0.80
Flash point (°C)	15	16	15	18	18	19
Fire point (°C)	20	21	20	24	25	24
Sulphur content (ppm)	2.4	2.2	2.5	2.6	2.6	2.9
Light gas (%)	5.7	5.6	5.9	6.6	6.0	6.2
Fuel yield (%)	88.3	88.9	89.1	50.8	52.5	55.6

Table-4: Parameters analysed for pyrolysis products of HDPE (With and without catalyst)

Parameters	Pyrolysis Temperature (°C)					
	Catalytic Reaction (°C)			Non-catalytic Reaction (°C)		
	380	389	385	380	389	385
Fuel density (g/ml)	0.78	0.78	0.79	0.82	0.81	0.84
Flash point (°C)	16	18	19	20	22	22
Fire point (°C)	21	20	20	25	24	26
Sulphur content (ppm)	3.3	3.8	3.6	3.8	4.1	3.9
Light gas (%)	5.2	5.4	5.4	5.6	5.8	5.5
Fuel yield (%)	89.8	89.0	89.6	54.5	53.8	56.2

Table-5: Parameters analysed for pyrolysis products of PP (With and without catalyst)

Parameters	Pyrolysis Temperature (°C)					
	Catalytic Reaction (°C)			Non-catalytic Reaction (°C)		
	400	402	398	400	402	398
Fuel density (g/ml)	0.76	0.77	0.76	0.79	0.81	0.80
Flash point (°C)	17	18	17	20	22	21
Fire point (°C)	20	22	23	24	25	25
Sulphur content (ppm)	1.1	0.9	0.8	1.4	1.1	0.9

Light gas (%)	2.1	2.3	2.5	2.3	2.5	2.6
Fuel yield (%)	92.3	91.8	92.8	56.4	54.2	56.8

Difference in the values of all these parameters between the catalytic and non-catalytic process was described for the fuel obtained from all three different types of plastic wastes. Fuels from LDPE, HDPE and PP plastic waste generated in the presence of activated carbon showed less flash point, fire point and specific density when compared to fuels generated in the absence of catalyst. According to Kanury (1983), the fuel with lower density value will have lower flash and fire point values. Generally, flash and fire points of any fuel are related to the handling safety.

Hence it is concluded that the fuel yield is higher in the presence of catalyst than in the absence of catalyst. And, the characteristics values of fuel from catalytic reactions are lower than the non-catalytic reactions indicating the safety of fuels generated in the presence of activated carbon.

4.Conclusion

Three different types of plastic wastes, HDPE, LDPE and polypropylene were subjected to degrade using pyrolysis method at varied temperatures. The reaction process was carried out in the presence and absence of catalyst. Activated carbon is used as catalyst during the reaction process. Low-emission fuel yield was obtained during the reaction process in the presence of catalyst. Different parameters for pyrolysis products like fuel density, plash point, fire point, sulphur content and light gas were recorded.

Maximum fuel yield percentage from LDPE waste was recorded as 89.1% in the presence of catalyst and 55.6% in the absence of catalyst at the 373°C. HDPE waste conversion at 385°C yielded 89.6% of fuel in the presence of catalyst and 56.2% of fuel in the absence of catalyst. Interestingly, pyrolysis of polypropylene generates maximum 92.8% of fuel in the presence of activated carbon and 56.8% of fuel in the absence of activated carbon at 398°C.

Activated carbon used as catalyst in the pyrolysis process influenced the yield and composition of the fuel. The characteristics values of fuel from the reaction in the presence of activated carbon are lower than the reaction in the absence of activated carbon indicating that the generated fuel is safe. Optimization of pyrolysis process using different catalyst will generate different types of fuels which can be experimented for domestic use in future.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. The work described in the manuscript is original and has never been submitted for publication elsewhere.

References

[1] M. N. Angyal, A. Bartha, and L. Valkai, "Fuels by pyrolysis of waste plastics from agricultural and packaging sectors in a pilot scale reactor", Fuel Process Technology, vol. 90, pp. 1032–1040, 2009.

[2] M. M. Nagarajan and G. Sampath, "Characterisation and effect of using waste plastic oil and diesel fuel blends in compression ignition engine", Energy, vol. 36, pp. 212–219, 2011

[3] M. N. Siddiqui and H. H, Redhwi, "Catalytic coprocessing of waste plastics and petroleum residue into liquid fuel oils", J Anal Appl Pyrol, vol. 86, pp. 141–147, 2009

[4] A.T. Yuliansyah, A. Prasetya, Muhammad A. A. Ramadhan, and R. Laksono, "Pyrolysis of plastic waste to produce pyrolytic oil as an alternative fuel", International Journal of Technology, vol. 7, pp. 1076-1083, 2015

[5] O. G. Piringer and A. L. Baner, "Plastic Packaging: Interaction with Food and Pharmaceuticals", 2nd

Ed., Wiley-VCH, Weinheim, Germany, p. 32. 2008

[6] Y. Abatneh and Omprakash Sahu, "Preliminary Study On The Conversion Of Different Waste Plastics Into Fuel Oil", International Journal of Scientific and Technology Research, vol. 2(5), pp. 226-230, 2013

[7] K. Murata, K. Sato and Y. Sakata, "Effect of pressure on thermal degradation of polyethylene", J Anal Appl Pyrol, vol. 7, pp. 569–589, 2004

[8] T. Faravelli, M. Pinciroli, F. Pisano, G. Bozzano, M. Dente, and E. Ranzi, "Thermal degradation of polystyrene", J Anal Appl Pyrol, vol. 60, pp. 103–121, 2001

[9] L. Sorum, M. G. Gronli, and J. E. Hustad, "Pyrolysis characteristics and kinetics of municipal solid wastes", Fuel, vol. 80, pp. 1217–1227, 2001

[10] M. Sarker and Mohammad M. Rashid, "First Simple and Easy Process of Thermal Degrading Municipal Waste Plastics into Fuel Resource", Journal of Engineering, vol. 2(9), pp. 38-49, 2012

[11] M. Syamsiro, H. Saptoadi, T. Norsujianto, P. Noviasri, S. Cheng, Z. Alimuddin, and K. Yoshikawa, "Fuel Oil Production from Municipal Plastic Wastes in Sequential Pyrolysis and Catalytic Reforming Reactors". Energy Procedia, Vol. 47, pp. 180–188, 2014

[12] P. Senthil Kumar, M. Bharathikumar, C. Prabhakaran, S. Vijayan and K. Ramakrishnan, "Conversion of waste plastics into low-emissive hydrocarbon fuels through catalytic depolymerization in a new laboratory scale batch reactor", Int J Energy Environ Eng, vol. 8, pp. 167–173, 2017.