SYNTHESIS OF ENERGY FUEL FROM PLASTIC WASTE AND ITS EFFICIENCY

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Abstract - *In this study, Catalytic pyrolysis of polypropylene (PP) plastics waste is carried out in the presence of Natural Zeolite powder in a Fix-Bed batch reactor to obtain an efficient liquid fuel. Natural zeolite has the potential to enhance the oil percent and one can obtain high calorific value fuel than that of oil without using catalyst. The process was carried out at the temperature of 500°C for the retention time of 1 hr at fast pyrolysis of 10°C/min. The Natural zeolite powder was modified by leaching solution of nitric acid into it and thermally activating at 500^0C for 3 hrs. The GCMS analysis shows the presence of olefins, paraffin and other compounds which are found in the conventional fuels. The gross calorific value of pyrolysis oil is 11000cal/kg which is similar to the calorific value of conventional diesel. Pyrolysis of plastic waste to energy fuel is expected to reduce the environmental pollution and increase the energy recovery.*

Key Words: Polypropylene waste, pyrolysis, natural zeolite, liquid oil, catalytic pyrolysis.

1. INTRODUCTION

Plastic waste has now become a major stream in MSW due to their increase in demand which leads to increase in production. The disposal of plastic waste is now considered to be a major environmental problem all over the world as plastic waste are not decomposed in the nature (tekin et al., 2012). The global plastic production was estimated at around 300 million tons per year and is continuously increasing every year (Miandad t al 2016; Ratnashri t al., 2017). The amount of plastic waste is estimated to be increased at a rate of 3.9% per year (A fivga et al., 2018). India generates 25,940 tons of plastic waste a day of which over 10,000 tons remain uncollected. As around 6300 metric tons of plastic waste have been generated as of 2015, out of these around 79% had been accumulated in landfills or natural environment, only 9% was recycled, and 12% incinerated (S.A. Salaudeen t al., 2019). Due to improper segregation and recycling system for these plastic wastes, load on landfill sites increases which ultimately cause environmental pollution and affects marine biodiversity. At MSW consist of about 50-70% of packaging materials comprising high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) (Aguado et al. 2006). Due to the increased demand and usage of polymeric materials as shopping bags, packaging materials, polyethylene terephthalate (PET) bottles and electrical appliances, most developing cities with even very low economic growth. Fossil fuel are now limited, non-renewable resources and continuous consumption will eventually lead to their decline, waste organic materials may become an important component in the drive toward alternative energy and petrochemical resources (Insura et al., 2010). It is suggested that plastic-based diesel (PBD) can be used as an alternative source of energy due to its similar physicochemical properties to that of conventional fuel. Petroleum is the main source of plastic manufacturing, the recovery of plastic to energy fuel through pyrolysis process had a great potential since the oil produced had high calorific value comparable with the conventional fuel.

Polypropylene waste contributes about 24.3% in plastic waste category which are the largest amount of plastic waste found in MSW after polyethylene (Anuar Sharuddin et al., 2016). Most plastic hinges, such as those on flip-top bottles, are made from polypropylene. The food containers made from polypropylene leaches toxins into the food and it has environmental problems throughout it's life cycle. Common application for polypropylene is with biaxial oriented polypropylene. Its sheets are used to make a wide variety of materials including clear bags. Polypropylene is also widely used in manufacturing carpets, rugs and mats to be used at home. The versatility of polypropylene is due to its good chemical resistance, mechanical properties, process ability, and its low density (D. Czajczyn´ska et al., 2017). Thus, Pyrolysis of polyproplyene with using catalyst has proven to be effective as compared to without using catalyst.

Catalyst have a very critical role in promoting process efficiency, targeting the specific reaction and reducing the process temperature and time (serrano et al., 2012; Ratnasri t al., 2017). Natural zeolite catalyst has gained significant importance for its potential environmental application and can be used to overcome the economic challenges of catalytic pyrolysis. In this research study natural zeolite is used as a catalyst because of its easy availability and cost effectiveness. The quality of the pyrolysis oil obtained by using natural zeolite is less as compared to the quality obtained by using synthetic zeolite. So, in order to improve the catalytic properties of the natural zeolite, natural zeolite is modified by thermal activation, leaching acid into it and wet impregnation method.

Environmentally, pyrolysis provides an alternative solution to landfilling and reduces GHGs, namely carbon dioxide (CO2) emissions. Pyrolysis has better environmental advantages compared to other MSW treatment methods (S. M. Al-Salem et al., 2016). Plastic pyrolysis on the other hand, may provide an alternative means for disposal of plastic wastes with recovery of gasoline range hydrocarbons (A. G. Buekens et al., 1998). In the process of pyrolysis, where heating occurs in the inert atmosphere in the presence of nitrogen or argon gas, the organic compounds are decomposed generating gaseous and liquid products, which can be used as fuels or sources of chemicals. The pyrolysis process takes place at moderate to high temperature (500^0C, 1-2 atm) in the absence of oxygen, the high temperature allows to break down the macrostructure of the polymer to form smaller molecules (Ragaert, K., et al. 2017). Thus, the catalytic pyrolysis presents a number of advantages over thermal, as it improves the quality and quantity of the fuel. The objective of this paper is to perform catalytic pyrolysis of the household polypropylene waste by fast pyrolysis using a low cost natural zeolite as catalyst as to improve the quality of the liquid oil.

2. MATERIAL AND METHODS

2.1. Materials:

The process is carried out at Chemical Laboratory, IIT Bombay. This experiment is performed by using thermal and acid activation of natural zeolite powder. Polypropylene waste basically used was bournvita and ice-cream containers. The plastic waste was washed properly with soap water, dried and then shredded into small pieces less than $1cm^2$. Natural zeolite was easily available and is very cheap as compared to other synthetic zeolite catalyst. The zeolite powder was heated at 500^0C for 3 hours to remove its impurities and by improving its property by leaching solution of nitric acid into it.

2.2. Pyrolysis reactor:

Figure 1. Fixed-Bed Batch reactor.

The catalytic pyrolysis was carried out in a fixed bed batch reactor. The reactor consist of:

1. nitrogen gas cylinder
2. heating mantle furnace
3. reactor
4. condenser
5. round bottom flask
6. gas sample bag

Figure 2. Oil collected into the vials

About 30g shredded polypropylene plastic waste and 3g of treated NZ catalyst was loaded into a reactor, the ratio of 1:10 was fixed as referred from the previous research study. The reactor was purged with nitrogen gas for 10 minutes at a pressure of about 5kg/cm2 in order to create the pyrolytic condition. Reaction was carried out at maximum temperature of 500^0C for 1 hour. The reactor was heated externally, as the temperature reached 500^0C the vapors were generated after depolymerisation of material were passed through condenser and oil obtained was collected in a round bottom flask.

2.3. Methods for analysis of oil

The GCMS analysis and the bomb calorimeter test are conducted at Trans-thane creek waste management association, Mahape.

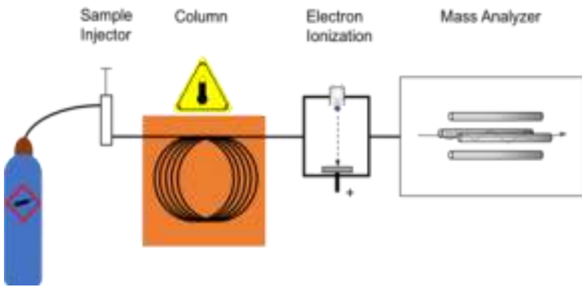

Figure 3. GC-MS analysis of the liquid oil

The GC-MS is composed of two major building blocks: the gas chromatograph and the mass spectrometer. The GC consist of a capillary column which depends on the column's dimensions i.e. length, diameter, film thickness. A gas chromatography with column Agilent 19091J-433: 325^0C: 30m x 250μm x 0.25μm is to be used for analysis of fuel oils. Different types of columns are used for different types of testing. There are two phases that is mobile phase and stationary phase, when the sample is injected in the inlet, it is carried out by carrier helium gas to the stationary phase. Helium gas is used because it is an inert gas and its property is not to react with other compounds. The temperature of the oven is kept 250^0c so that the stationary phase is suitable and remain stable at 250^0c. The gas is carried into the stationary phase i.e. into the column. The molecules with low boiling point will move faster in the column. The molecules are retained by the column and then elute (come off) from the column at different times (called the retention time), and this allows the mass spectrometer downstream to capture and detect the ionized molecules separately. The mass spectrometer breaks each molecule into ionized fragments and detects these fragments using their mass to charge ratio.

Figure 4. Bomb calorimeter Test

Bomb calorimeter test is done to determine the amount of heat that is given off or taken in by a reaction. It is a type of constant-volume calorimeter used for measuring the heat of combustion of a particular reaction. It withstand the large pressure within the calorimeter as the reaction is being measured. In order to ignite the fuel Electrical energy, as the fuel is burns, it will heat up the surrounding air, expands and escapes through a tube that leads the air out of the calorimeter. The water outside the tube heats up when the air is escaping through the copper tube. The change in temperature of the water allows for calculating calorie content of the fuel.

3. RESULTS AND ANALYSIS

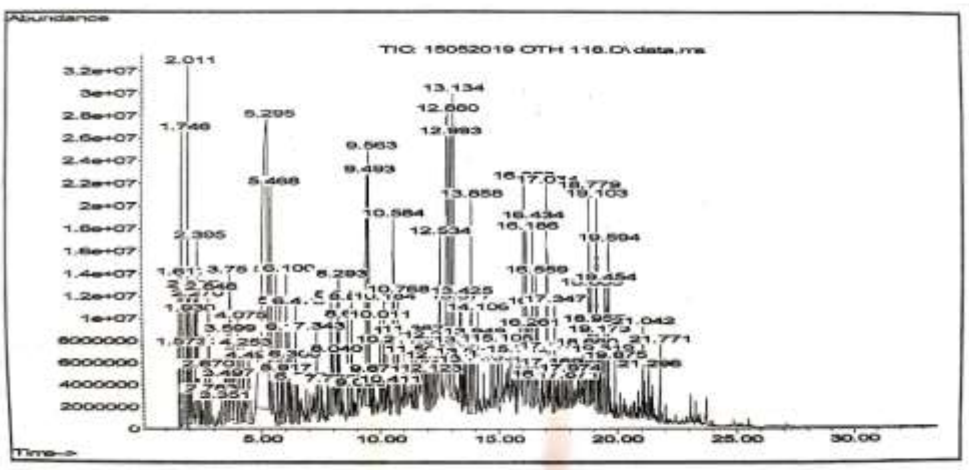

Figure 5. Peak areas of the compound obtained during GCMS analysis

The GCMS analysis was carried out to identify the chemical compounds present in the liquid oil which is obtained from the catalytic pyrolysis of waste polypropylene in the presence of natural zeolite catalyst at 500^0C. The chemical compound which is first identified has the low boiling point, were ordered accordingly to increasing retention time as shown in table 1. The identified compound were mostly alkanes and alkenes due to the branched structure of polypropylene. Hydrocarbons such as trimethylcyclohexane, dimethylhexene, 1-isopropyl-1,4,5-tetramethylcyclohexane, 13- dimethyl-12-tetradecen-1-ol acetate was mostly present. The degradation of polypropylene is ended in disproportionation.

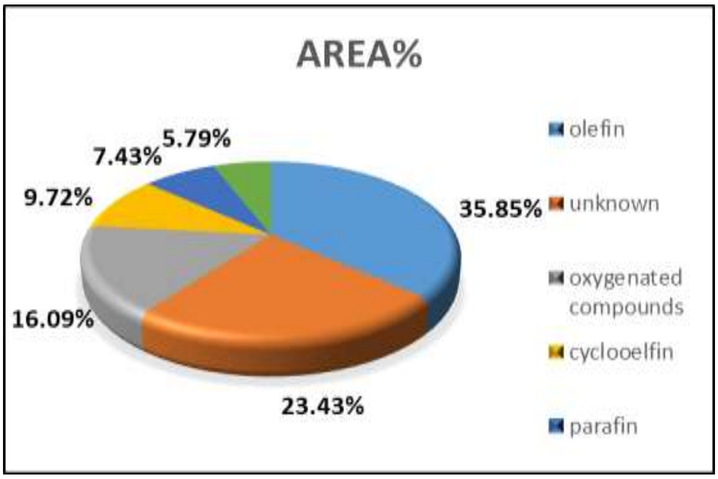

Figure 6. Bar chart of the chemical composition of the liquid oil

Hence, the chemical composition of the liquid consist of olefin, paraffin and other compounds as shown in the figure 3. The calorific value of liquid by using bomb calorimeter was found out to be 11000 cal/kg.

4. CONCLUSION

Catalytic pyrolysis of waste plastics using low cost natural zeolite catalyst has been investigated to yield pyrolysis oils as in replacements for commercial liquid fuels such as diesel and petrol. Pyrolysis of polypropylene waste was achieved at a lab scale to produce useful fuel products. Different type reactors requires different parameters for the degradation of plastic which can affect the quantity of the liquid. Importantly, the addition of treated NZ catalyst successfully yielded liquid based fuel. The GCMS analysis shows the presence of olefins, paraffin, cyclooelfin, cycloparaffin and other compounds which are found in the conventional fuels. The gross calorific value of pyrolysis oil is 11000cal/kg which is similar to the calorific value of conventional diesel. Importantly, the use of catalyst reduced pyrolysis processing time to only 20-25 minutes for 30g of plastic waste. The quality of the liquid oil is improved by using natural zeolite, only one should get the parameters accurately in pyrolysis process. The application of inexpensive and widely available NZ catalyst in pyrolysis could significantly aid in repurposing plastic wastes.

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