

COMPARATIVE STUDY OF CATALYTIC PYROLYSIS OF WASTE POLYPROPYLENE (PP) USING SILICA –ALUMINA, KAOLIN CLAY AND CALCIUM BENTONITE CATALYST

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ABSTRACT

The globally plastic produced expanded over years because of the variety applications of plastics in various sectors that caused the accumulation of waste plastic in the landfill. The growth rate of plastic demand obviously affected the resources of petroleum availability as non-renewable fossil fuel since plastics were the petroleum-based material. Some options that have been considered for waste plastic management were recycling and energy recovery methods. The present work involves the comparative study of catalytic pyrolysis of waste polypropylene (PP) using various type of catalyst such as silica alumina, kaolin clay and calcium bentonite. The effect of silica alumina, which has been extensively studied by different investigators for the pyrolysis of waste polypropylene and compared with that of catalytic performance of kaolin and calcium bentonite. From the study it is found that silica alumina is found to be best as a catalyst for the degradation of plastics waste to liquid fuel and valuable chemicals and also improved the yield fraction and reaction time. From the optimization study it is found that, the maximum oil yield in thermal pyrolysis of polypropylene waste was 84 wt% at 500°C. and the maximum oil yield in catalytic pyrolysis with using silica alumina was 91 wt% at 500°C with feed ratio of plastic to catalyst 3:1. The rate of reaction, oil yield and quality of oil obtained in the catalytic pyrolysis using silica alumina catalysts are significantly improved compared to the thermal pyrolysis and catalytic pyrolysis using kaolin and calcium bentonite catalyst. The fuel properties of the produced oil with the help of catalytic pyrolysis of polypropylene are same as that of petro-fuels. Therefore, they can be used directly as an fuel after fractionation of liquid.

Keywords: Pyrolysis, catalyst, silica-alumina, kaolin clay, calcium bentonite, fuel.

INTRODUCTION

Economical growth of plastic, consumption of plastic and production patterns are rapidly increases in the production of plastic waste in the world. Waste plastic is a potentially cheap source of chemicals and energy. Now a days different different types of products are made of plastic materials. Due to increase in generation, waste plastics are becoming a major problem in solid waste. Due to food waste, paper waste, plastics consumption are increases. Generating more waste plastic due to plastic packaging, plastic shopping bags, PET bottles and others components and products which uses plastic as a major component. Due to lack of integrated solid waste management, most of time waste of plastic is neither collected in proper manner nor disposed of in appropriate manner to avoid this impacts on environment and public health and waste plastics are also due to choking of sewerage system. The plastic has achieved such an extensive market due to fact that it is lightweight, cheap, flexible, reusable, do not rust or rot, and so forth. Because of this, plastics generation has gone up by about 10% every year on a world basis since 1950 [1]. Asia accounts for 36.51% of the worldwide consumption and has been world's largest plastics consumer for several years. The major segment continues to be the packaging, which has accounted for over 35% of the global demand [2]. The total world wide production of plastics has increases from about 1.3 million tons in 1950 to 244 million tons in 2006. An analysis of the plastics consumption on a per capita basis show that the plastics has now grown to over 100 kg/year in North America and Western Europe with the potential to grow up to 130 kg/year per capita in 2010 according to survey.

According to the report of the (CPCB) Central Pollution Control Board. Thus, the CPCB estimate of plastic waste produced in India about 660,787.86 tons in 2017-18, enough to fill 66,079 12 trucks at 10 tons a truck does not reflect the situation in more than 61% of India's states and union territories. The total waste plastics generation figure for that year was estimated at 1.6 million tons, or 160,000 truck fulls. India consumes an approx 16.41 million tons, about 1.61 million truck fulls of plastic annually, according to the report June 2018 in Down to Earth that cites data provided by Plast India Foundation, a selection of associations and institutions that

they have deal in plastic. Of this, 43% is plastic manufactured for only single-use packaging materials that will mostly find its way into garbage bins, according to some reports. In all, 80% of total plastic generated in India is discarded.

Suitable reuse and recycling methods or waste reduction strategies are the need of the hour, as it is impossible to ignore the use of plastics altogether due to their diversified applications [3]. Among various waste plastic management options, pyrolysis is getting attention as it provides an opportunity of converging plastic waste materials of low-energy density into high-energy density fuels and recovery of high value chemicals. Pyrolysis reaction involves the thermo-chemical decomposition of organic material in the absence of oxygen. pyrolysis reaction has a lower temperature process and it can be say negligible emissions of air pollutants. And which have ability to handle unsorted plastic, unwashed plastic, thus could become the most appropriate to be developed into plastic waste to energy recycling process [4] The conversion methods of waste plastic into fuel depend on the types of plastics to be used and the properties of other wastes that might to be used in the process. In general, the conversion of plastic waste into fuel required feedstocks which are non-hazardous and combustible.

Catalytic pyrolysis of waste plastic has significant advantages over thermal as the catalyst help lowering temperatures, enhancing the reaction rate and yield fuels fraction.

PREPREATION OF CATALYST

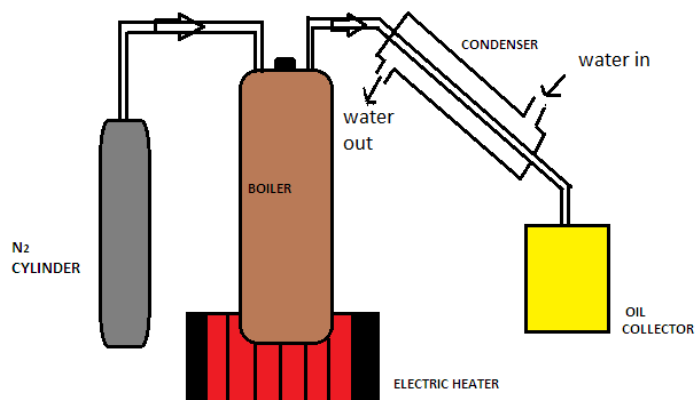
Silica Alumina was obtained from the Chemtex Corporation, Kolkata, India. The chemical composition of the Silica Alumina sample was found to be SiO₂ 42.45%, Al₂O₃ 35.1300%, Fe₂O₃ 1.3100%, MgO 1.1060%, CaO 2.1430%, ZnO 0.0064%, K₂O 0.4410%, TiO₂ 0.5600%, LOI at 1000 °C 16.82%. Silica-aluminas are a family of materials characterized by mediumstrong tunable acidity.[5] The surface area and acidity of the sample was found to be 29 m²/g and 0.214mmol NH₃/g respectively. The products of coprecipitation and cogelling of silica and alumina, generally denoted as silica-aluminas, represent a family of very useful chemicals in the field of adsorption and catalysis.[6] They are solid acids with tunable acid strength in terms of amount of Lewis acid sites of different strengths and amount of Brønsted sites characterized by medium strength. They are also substantially stable materials at relatively high temperatures (up to 500–700 °C).[7]

The Kaolin clay material obtained from Chemtex Corporation, Kolkata, India which used as catalyst in the pyrolysis reaction process.[8] The chemical composition of the kaolin sample was found to be SiO₂ 43.12% Al₂O₃ 46.07 %, Fe₂O₃ nil, MgO 0.027 %, CaO 0.030 %, ZnO 0.0064%, K₂O 0.01%, TiO₂ 0.74, LOI at 1000 °C 9.9%.he BET surface area of kaolin was found to be 23m²/g. The pore size distributions of kaolinite samples showed a sharp peak at a radius of 3.51nm, thus it is mesoporous.[9]. The acidity of the kaolin determined using ammonia-temperature programmed desorption method was 0.04 mmol NH₃/g.[10].

The calcium Bentonite clay was procured from The Benzenikx Pharma and Industrial Products Pvt. Ltd., Hyderabad, India.[11] The XRF composition of the calcium bentonite clay is SiO 2:53.02, Al₂O₃:20.34, Fe₂O₃:9.39,TiO₂:1.14, Na₂O: 0.33, CaO: 4.85, P₂O₅:0.03, V₂O₅:0.09, MnO0.08, LOI: 10.72 The BET surface area of the clay was found to be 146 m²/g. The TG plot of the clay sample ensures that the thermal stability, as there is small weight loss up to 700°C, which must be causes physio-adsorbed water only and thus clay could be used in pyrolysis process below 700°C temperature.[12]

MATERIALS AND METHODS

Waste polypropylene is selected as the source of raw material in our study it comprises a prominent percentage of the waste plastic produced. The catalyst identified for the study include silica alumina, kaolin clay and calcium bentonite. The pyrolysis reaction is carried out in the plastic to catalyst ratio of 3:1 .the reaction temperature range between 400°C to 550°C. The inert atmosphere for the pyrolysis reaction is provided by using nitrogen as a carrier gas, and the flow rate is fixed to be 10 mL/min. A schematic sketch of the experimental process setup is as shown in Figure. The process consists of a electric heater, Boiler, condensers and oil collectors, and a nitrogen source (inert gas). The maximum loading capacity of the reactor was 1 kg of waste plastics in our study. Waterat below 10°C is used as the coolant in the condesor.

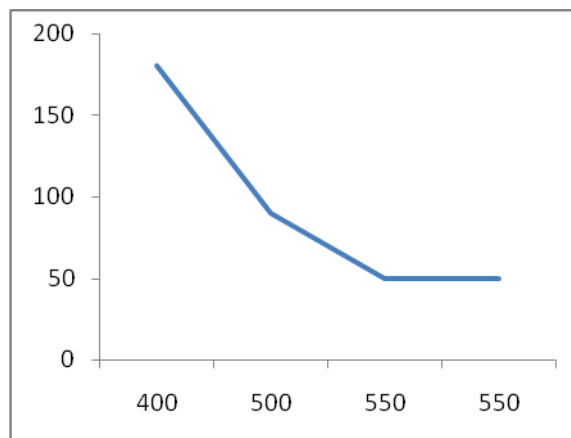
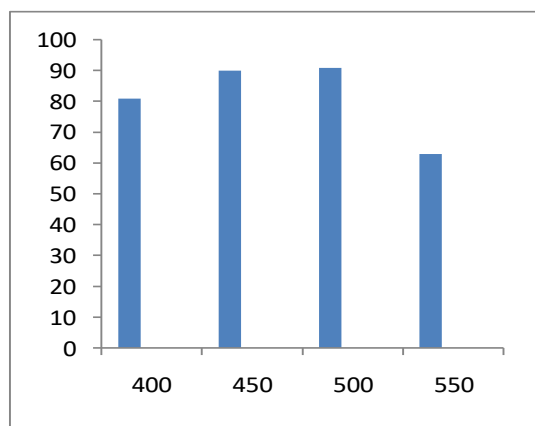


The waste polypropylene was mixed with the catalyst in the ratio of 3:1 before it is being supplied to the reactor. For using of each catalyst such as silica alumina, kaolin clay and calcium bentonite. And these mixed polymer to catalyst material feed into the container. The pyrolysis reactor was fixed vertically, and nitrogen gas used as a inert gas which was introduced into the reactor. The flow of nitrogen into reactor replaces the air from the reactor and allows the pyrolysis reaction under anaerobic condition. Before start the heating, nitrogen gas is permit to flow through the heater unit to remove the oxygen which is present initially. Then heater is switched on, and the temperature controller is set to the range of 400°C to 550°C temperature and process carried out for some times. The vapor fraction formed during the pyrolysis of the plastic inside the reactor flows out of the reactor through condenser for condense the vapor in which water is supplied for the colling action. The cooling water for the condenser is at a temperature of 10°C. Low temperature for water is provided by an external cooling system setup. The condensed liquid fraction is finally collected in the collecting tanks and is filtered. Then further proceed for the testing of these produced yield oil. Now this process is repeated for different temperatures for various catalysts.

RESULT AND DISCUSSION

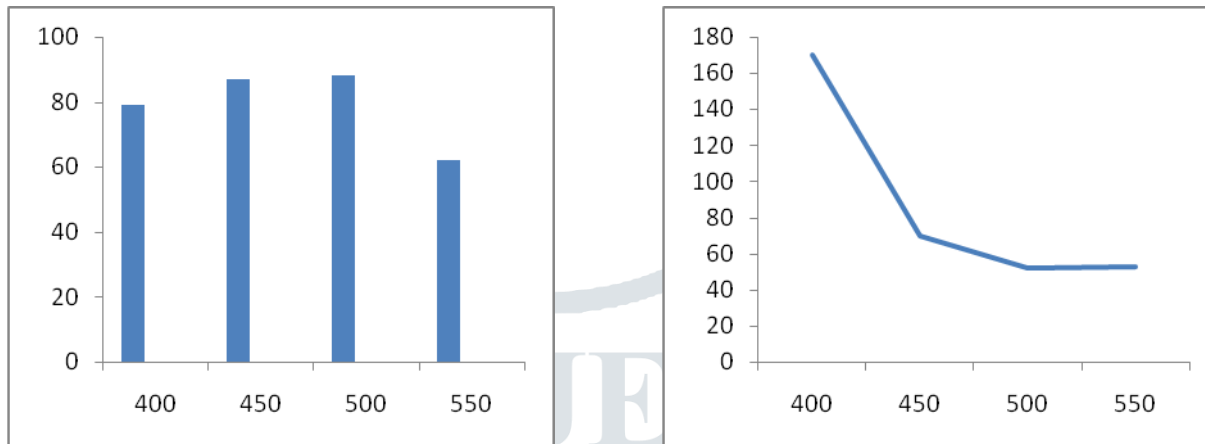
EFFECT OF PRESENCE OF SILICA ALUMINA CATAYST

The pyrolysis reaction of polypropylene (PP) was carried out in the presence of silica alumina catalyst. The catalytic reactions was carried out by taking the ratio of 1:3 (catalyst to polypropylene ratio) at different different temperature range from 400°C to 550°C. we have observe that using silica –alumina catalyst the maximum yield fraction was obtained 91 wt% at 500°C at the ratio of plastic to catalyst 3:1.



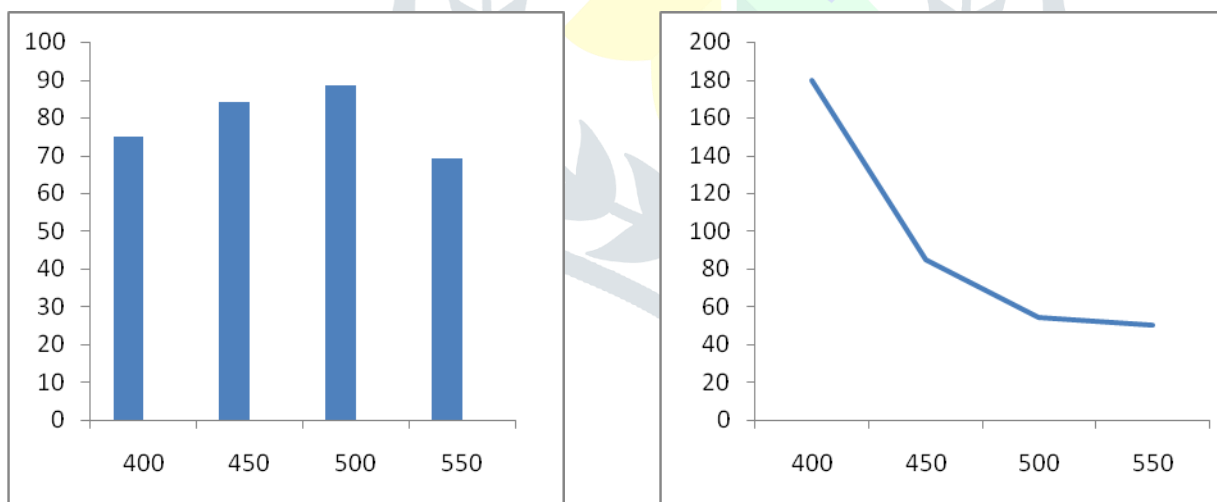
EFFECT OF PRESENCE OF KAOLIN CLAY CATALYST

The pyrolysis reaction of polypropylene (PP) was carried out in the presence of Kaolin clay catalyst. The catalytic reactions were carried out by taking the ratio of 1:3 (catalyst to polypropylene ratio) at different different temperature range from 400°C to 550°C. we have observe that using kaolin clay catalyst the maximum yield fraction was obtained 88 wt% at 500°C at the ratio of plastic to catalyst 3:1.



EFFECT OF PRESENCE OF CALCIUM BENTONITE CATALYST

The pyrolysis reaction of polypropylene (PP) was carried out in the presence of Calcium bentonite catalyst. The catalytic reactions were carried out by taking the ratio of 1:3 (catalyst to polypropylene ratio) at different different temperature range from 400°C to 550°C. we have observe that using calcium bentonite catalyst the maximum yield fraction was obtained 88.5 wt% at 500°C at the ratio of plastic to catalyst 3:1.



FUEL PROPERTIES OF OIL

Test	Si-Al catalysed oil at 500°C with plastic to catalyst ratio = 3:1	Kaolin catalysed oil at 500°C with plastic to catalyst ratio = 3:1	Calcium bentonite catalysed oil at 500°C with plastic to catalyst ratio = 3:1
Colour	Yellow	Yellow	Yellow
Specific gravity @ 15°C/15°C	0.7711	0.7776	0.7210
Calorific value(MJ/kg)	11.262	11.256	44.37
Pour point(°C)	< - 45	< - 45	< - 40
Cloud point(°C)	< - 45	< - 45	< - 40
Flash point(°C)	< - 12	< - 12	< - 22
Fire point(°C)	< - 12	< - 12	< - 18
Boiling point range(°C)	68-346	59-341	60-325

CONCLUSION

Waste polypropylene (PP) are cracked catalytically in the presence of Si-Al, Kaolin clay and Calcium Bentonite catalyst in a fixed bed reactor in the temperature range 400°C to 550°C in order to optimized the suitable condition and suitable catalyst for the production of liquid fuel. The process of pyrolysis depend on the temperature, effect of catalyst and feed composition. The highest yield of pyrolysis liquid produced was 91(wt)% at 500°C with feed of plastic to catalyst ratio 3:1 with using Si-Al catalyst and also decrease reaction time. In overall study we have concludid that the best catalyst for the pyrolysis of polypropylene is Silica Alumina (Si-Al) catalyst other than these two catalyst and this catalyst also provide best quality and quantity of produced liquid.

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