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Liquid Fuel From Polypropylene Plastic Wastes with Bentonite as Catalyst by Catalytic Cracking Process

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Abstract. The aim of this project work is to convert waste plastics into useful fuel range hydrocarbon mixture. The catalytic cracking process of polypropylene plastic waste (mineral water cup) was performed in a fixed-bed reactor with bentonite catalyst, at five temperatures ranging from 150 to 350 °C with percent catalyst of 4%.The amounts of liquid fuel produced, as well as the compositions of the resulting liquid fuel, were determined by Gas Chromatography-Mass Spectrometry. The influences of cracking parameters, such as temperature and catalyst mass, on product yields were investigated. The optimum conditions cracking of polypropylene plastics waste with bentonite as catalyst is at temperature of 350 °C with 4% catalyst mass or 20 grams. The highest liquid yield (41.5%) was obtained using 20 gram Bentonite catalyst at 350 °C. The highest percent composition of C_6H_{14}, C_7H_{16} and C_8H_{18} in liquid product is 16.92%, 18.48%, and 12.22% respectively at temperature of 350 °C. Results from this research are expected to provide benefits in terms of producing a type of fuel oil that can be used as petroleum substitution, resolve the fossil fuel energy crisis and enhance the environment's quality by decreasing the amount of plastic waste that has been a huge concern because of its undegradable characteristic

Keywords : bentonite, catalytic cracking, liquid fuel, polypropylene, waste plastic to fuel

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Introduction

Many countries are currently modifying their energy and waste management systems. Global climate change, which is caused by growing levels of carbon dioxide (CO_2), methane (CH_4), and other greenhouse gases, is one of the main causes of these changes. As a result of this concern, the international community agreed to join the Kyoto Protocol in 1997, which only requires rich countries to cut emissions by 5% by 2010 compared to 1990 [1].

Plastic trash from both sectors and homes has increased dramatically. According to preliminary figures given by Plastics Europe, global plastics manufacturing increased to 280 million tons in 2011. Between 2010 and 2016, the global consumption of plastics is expected to grow at a rate of roughly 4% per year. It'll be the same as the amount of waste produced [2].

Plastic usage has increased in Indonesia, as it has in many other developing countries, as a result of economic expansion and growing urbanization. Indonesia consumed 10 kilogram of plastic per capita per year in 2011. Plastic garbage accounted for 9.96 percent of municipal solid waste in Yogyakarta, Indonesia [3].

Landfilling and incineration currently account for the majority of plastic waste disposal [1]. As a result, pollution in the environment is becoming more prevalent every day. Plastic waste is the main source of pollution in the environment. There are three approaches to manage plastic garbage. There are three options: landfill, incineration, and recycling. The problem of wastes cannot be managed by land filling and burning since suitable and safe depots are expensive, and incineration accelerates the buildup of hazardous greenhouse gases including NOx, SOx, and COx. [1]. As a result, this study employed the recycling method. Cracking, gasification, hydrolysis, and other methods of recycling are only a few examples. Cracking, often known as thermal cracking, is the most appealing of these recycling techniques [4].

In the presence of an inert gas, such as nitrogen, cracking is the thermal breakdown of materials. Cracking is the term for the thermal degradation of materials in the presence of an inert gas like nitrogen. The macromolecular structures of polymers are broken down into smaller molecules during the cracking process. It is possible to lower the temperature of the process. A gas fraction, a liquid fraction including paraffins, olefins, naphthenes, and aromatics, and solid residues can be isolated from the pyrolytic products. Thermal cracking and catalytic cracking are the two types of cracking processes. Polymeric materials crack when heated in the absence of oxygen. Temperatures ranging from 350°C to 900°C cause thermal cracking. A appropriate catalyst is used to carry out catalytic cracking. When a catalyst is present, the temperature and reaction time are both lowered. Catalysts aid in the conversion and purity of fuel [5].

Converting plastic waste into source of energy is an alternative. Many researchers have looked into the possibility of turning plastic into valuable materials for use as energy sources [6]. Catalytic cracking is used to manufacture liquid fuel from a mixture of raw materials such as HDPE, LDPE, PP, and PS using a ZnO catalyst. To achieve the desired temperature, the reactor was heated electrically (200-400 °C). According to the findings, PP has the highest heating value among the mixtures, resulting in a high yield conversion (87%).

Using Catalytic Cracking to Produce Fuel Range from Municipal Waste Plastics Hydrocarbons utilizing Bentonite, [7] uses Bentonite as a catalyst in the cracking process to produce liquid fuel from PP and LDPE. The reactor is gradually heated to temperatures of 430-450 degrees Celsius. Polypropylene and its mixtures with LDPE can be catalytically destroyed to give a considerable volume of oil with a 60 percent yield (wt basis).

Processing of Polypropylene (PP) Plastic Waste Into Liquid Fuel by Catalytic Cracking Method Using Synthetic Catalyst [8], Using a batch reactor at temperature of 350, 400 and 450 °C for 60 minutes and use synthetic catalyst from fly ash and NaOH called as Zeolit X. The result from the research shows that with the highest variation of temperature the yield conversion can reach 76.09% which is a quite high value.

PP is a linear hydrocarbon chain saturated polymer that is chemically and thermally robust. Unlike HDPE, PP does not melt below 160 degrees Celsius. It has a lower density than HDPE, but it is harder and stiffer, making it a better choice for the plastics industry. Around 24.3 percent of the plastic wastes group, which includes the most plastics in MSW, is made up of PP. Among the many uses are flowerpots, office folders, automotive bumpers, pails, rugs, furniture, storage boxes, and other goods. Because of the increased need for PP in everyday life, the amount of PP waste produced grows every year, cracking of PP is one of the energy recovery technologies available. Several studies have studied the liquid oil output and characteristics of PP cracking at various settings [9].

Experimental

Time and Place of Research

This research was conducted from August to December 2016 at the Sriwijaya State Polytechnic Energy Laboratory. Analysis of the characteristics of the fuel oil will be carried out at the Organic Laboratory of Gadjah Mada University.

Raw material

The plastic wastes materials used in the study were collected from Plastic's Recycle place in Plaju, South Sumatera, while the Bentonite catalyst is supplied by PT Bratachem.

Equipments

Equipment used were cracking Unit, beaker glass 50 ml, beaker glass 100 ml, analytical scale, measurement glass, measurement pipette, spatula, scissors, pycnometer, Gas Chromatography-Mass Spectrometry, furnace, and crusible.

Research Procedure

Initial raw materials were collected from Plastic's Recycle place in Plaju. PP is in the form of mineral water cups. In that place, the initial raw material was washed and cut into little pieces of plastics used grinding machine. The already clean and cut plastics then dried in room temperature for about 30 minutes. Each conversion procedure was carried out with 500 grams of polypropylene waste plastics combined with Bentonite catalyst at 4%, 6%, and 8% of the weight of the raw material, respectively. Bentonite has to be activated by heating it to 300°C for 3 hours before it could be utilized. The temperature of the operation was set to 250°C, and the duration was set to 20, 40, and 60 minutes. Reactor, condensation unit, liquid fuel collection tank, radiator, and a small pump were all necessary for this experiment. Temperatures were constantly monitored and controlled in the manufacturing process. The operating time was computed based on the fact that the liquid vapor was now being dripped first. It was also calculated how much fuel oil was created. The fuel oil will then be collected and sealed for additional investigation, including GC-MS analysis, density testing, and engine performance testing.

The procedure of this research can be seen in the flow diagram below:

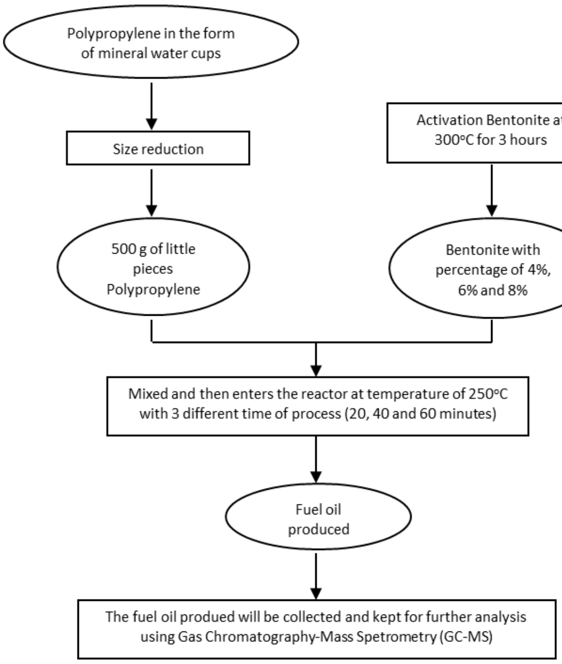

Figure 1. Flowchart Diagram of Polypropylene Conversion Process into Fuel

Results and Discussion

Results

Catalytic cracking converts waste polypropylene polymers into liqid fuel, resulting in liquid, gas, and solid residue. Polypropylene plastics waste catalytic process carried out on the variation of 4, 6, and 8 % of Bentonite catalyst with temperature 250 °C. The main focus of this research is liquid yield. The detailed product distribution is as listed in Table 1.

The result showed that catalyst mass and length of cracking time play an important role in catalytic cracking process, particularly production of liquid. In majority, liquid product produced increases along with the increasing length of cracking time. Catalytic cracking converts waste plastic's lengthy chain of hydrocarbons (polymer) into shorter chain hydrocarbons that resemble fuel.

Three distinct products emerged from the catalytic cracking process (liquid, gas and solid). Table 2 shows the yield % of product obtained.

Tables 1 and 2 show that a 4 percent catalyst, 60-minute cracking duration, and 14.06 percent liquid output resulted in the highest conversion of 82.16 percent, followed by 70.3 gram. The parameters of fuel oil after cracking at 250 °C are shown in Table 3.

The product with 8% catalyst and a 60-minute cracking time is the greatest option when compared to ordinary gasoline. In addition, the product with 8% catalyst and a 60-minute cracking period had the highest conversion rate. The temperature of the experiment was then varied from 150 °C to 200 °C to 300 °C to 350 °C. Tables 4 through 6 show the results.

Effect of Cracking Time Process and % Catalyst Towards the % Yield of Liquid Product at 250 °C

Figure 2 shows that as the cracking duration and catalyst increase, so does the % conversion of

Table 1. Weight of Product from Cracking Condition at 250°C of PP Plastics Waste

No.	Weight Catalyst (%)	Reaction Temperature (° C)	Length of Cracking Time (minutes)	Measured Parameter Liquid (gr)	Gas (gr)	Solid (gr)
1.	0	250	20	28.7	335.8	135.5
2.			40	31.2	338.6	130.2
3.			60	34.1	343.6	122.3
4.	4	250	20	50.2	351.2	98.6
5.	6			42.3	348.3	109.4
6.	8			32.2	339.2	128.6
7.	4	250	40	65.5	343.8	90.7
8.	6			52.1	350.4	97.5
9.	8			34.2	244.1	121.7
10.	4	250	60	70.3	340.5	89.2
11.	6			59.1	347.2	93.7
12.	8			35.7	344.1	120.2

Table 2. The Conversion and Yield of Products from Cracking Condition at 250 °C

No	Weight Catalyst (%)	Reaction Temperature (° C)	Length of Cracking Time (minutes)	Conversion (%)	Liquid (%)	Gas (%)	Solid (%)
1.	0	250	20	72.9	5.7	67.2	27.1
2.			40	73.9	6.2	67.8	26.0
3.			60	75.5	6.8	68.7	24.5
4.	4	250	20	80.3	10.4	69.9	19.7
5.	6			78.1	8.6	69.6	21.8
6.	8			74.2	6.4	67.9	25.7
7.	4	250	40	81.8	13.1	68.8	18.1
8.	6			80.5	10.4	70.1	19.5
9.	8			75.6	6.8	68.9	24.3
10.	4	250	60	82.1	14.6	67.6	17.8
11.	6			81.2	11.8	69.5	18.7
12.	8			75.9	7.1	68.9	24.0

the product, and vice versa. The percent conversion of products is 75.96%, 75.66%, and 74.28 % after 20 minutes of cracking time with the catalysts of 4%, 6%, and 8% at a temperature of 250°C.

The percent conversion of products is 78.12%, 75.66 %, and 75.96 % after 40 minutes of cracking time with the catalyst at temperatures of 250°C.

Table 3. Fuel Oil Characteristic of PP Plastics Waste from Cracking Condition at 250°C

	Research Variable			**Analyzed Parameters**		
No	Weight Catalyst (%)	Reaction Temperature (° C)	Length of Cracking Time (minutes)	Density (g/ml)	Spgr	API Gravity
	Standard Parameter of Gasoline			0.71-0.77	0.7528	50.46
1.	0	250	20	0.725	0.739	59.8
2.			40	0.734	0.749	57.4
3.			60	0.753	0.768	52.7
4.	4	250	20	0.757	0.773	51.6
5.	6			0.728	0.743	58.9
6.	8			0.756	0.771	51.9
7.	4	250	40	0.764	0.779	49.9
8.	6			0.746	0.762	54.3
9.	8			0.772	0.788	48.1
10	4	250	60	0.767	0.783	49.2
11	6			0.777	0.792	47.1
12	8			0.785	0.801	45.2

Table 4. Weight of Product from Varied Cracking Condition of PP Plastics Waste

No	**Weight Catalyst (%)**	**Reaction Temperature (°C)**	**Length of Cracking Time (minutes)**	**Measured Parameter**		
				Liquid (gr)	**Gas (gr)**	**Solid (gr)**
1.	4	150	60	54.2	349.1	96.7
2.		200	60	65.9	343.9	90.2
3.		300	60	72.9	338.9	88.2
4.		350	60	86.7	327.4	85.9

Table 5. The Conversion and Yield of Products from Varied Cracking Condition

No	**Weight Catalyst (%)**	**Reaction Temperature (°C)**	**Length of Cracking Time (minutes)**	**Conversion (%)**	**Liquid (%)**	**Gas (%)**	**Solid (%)**
1.	4	150	60	80.7	10.8	69.8	19.3
2.		200	60	81.9	12.2	68.8	18.0
3.		300	60	82.4	14.6	67.8	17.6
4.		350	60	82.8	17.3	65.5	17.2

Table 6. Fuel Oil Characteristic of PP Plastics Waste From Varied Cracking Condition

No	**Research Variable**			**Analyzed Parameters**		
	Weight Catalyst (%)	Reaction Temperature (° C)	Length of Cracking Time (minutes)	Density (g/ml)	Spgr	API Gravity
1.	4	150	60	0.757	0.772	51.7
2.		200	60	0.759	0.775	51.1
3.		300	60	0.765	0.781	49.8
4.		350	60	0.767	0.782	49.4

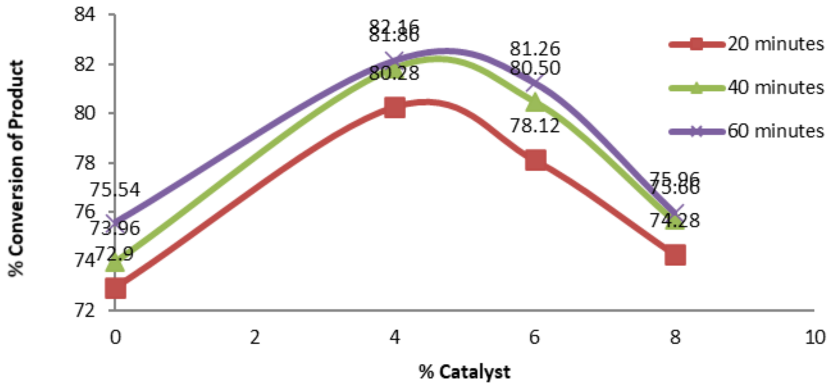

Figure 2. Effect of Cracking Time Process and % Catalyst Towards the % Yield of Product

Cracking time had a positive impact on product conversion percentage, as illustrated in Figure 2. The conversion % grew as the cracking process took longer [10] argued that because the reactant would shatter completely with time, the longer it was reacted, the more product was created. As a result, 60 minutes was found to be the ideal time for breaking polypropylene since the longer the process ran, the more raw material was turned into product. When it comes to catalysts, cracking without one has the lowest conversion value. It was because without a catalyst, the cracking process was known as thermal cracking (thermal cracking), which required high temperatures and typically resulted in low-quality products.

Catalysts can improve this technique by reducing the temperature and reaction time, allowing for the production of higher-value hydrocarbons. Catalyzed cracking accelerates these breakdown processes by allowing them to occur at lower temperatures and for shorter periods of time. As a result, catalytic cracking offers several advantages over thermal cracking, such as decreased energy consumption and product generation with a smaller carbon atom dispersion, which may favor high-value aromatic hydrocarbons [11].

Product conversion was higher with a catalyst in this experiment than without. Because a catalyst might theoretically increase the cracking reaction of the cracking gas, too much catalyst can reduce the liquid fraction while increasing the gaseous fraction [12], the maximum product conversion was reached by a 4% catalyst variation.

The study's purpose was to get the maximum product conversion rate possible [12], who looked into Polypropylene with an Activated Carbon catalyst, also pointed out that employing too much catalyst could lead the product distribution to mirror that of a non-catalyzed process, especially at higher temperatures. As a result, product conversion from 6 and 8% catalyst cracking methods has dropped, as seen in the graph. As a consequence, the ideal Bentonite percentage for thermal-catalytic cracking with Polypropylene as a raw material was found to be 4%.

The effect of cracking duration and catalyst percentage on liquid product yield percent followed the same pattern as product conversion percentage, suggesting that the two are linked: the more liquid product produced, the higher the conversion percentage. The amount of liquid product produced is affected by the length of the crack and the catalyst fraction, as shown in Figure 3.

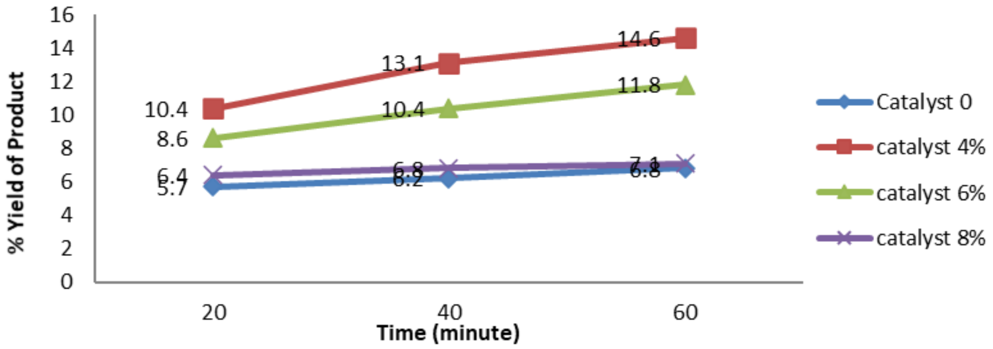

Figure 3. Effect of Cracking Time Process and % Catalyst Towards the % Yield and %Conversion of Liquid Product

The yield of liquid product grew with time as more raw material was broken, implying that liquid product output was linearly proportional to time [2] claimed that the higher the catalyst percentage, the higher the product yield, but that this would reduce over time. This occurred because the catalyst did not convert all of the plastic molecules to a simpler chemical using all of its pores. With Polypropylene as the raw material and Bentonite as the catalyst, the optimal time for cracking and percentage of catalyst addition was 60 minutes and 4% catalyst addition.

The two graphs followed the same pattern, as shown in figures 4 and 5, with the greater the process temperature, the higher the product conversion and yield %. At 350°C, the liquid product conversion and yield did not appear to drop, indicating that this was not the process's limit. Several investigations have indicated varied tendencies when it comes to a process's temperature limit.

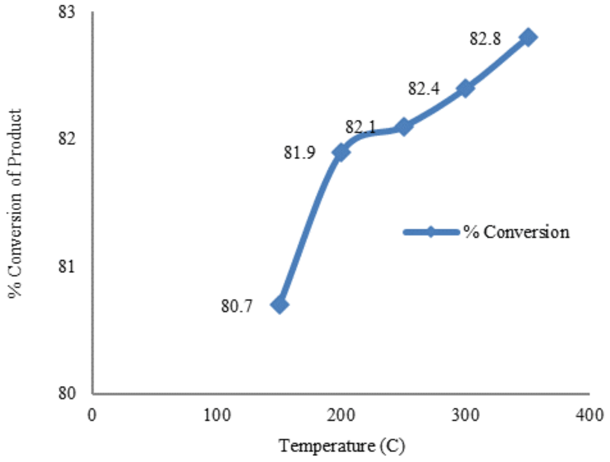

Figure 4. Effect of Various Temperatures Towards % Conversion of Product

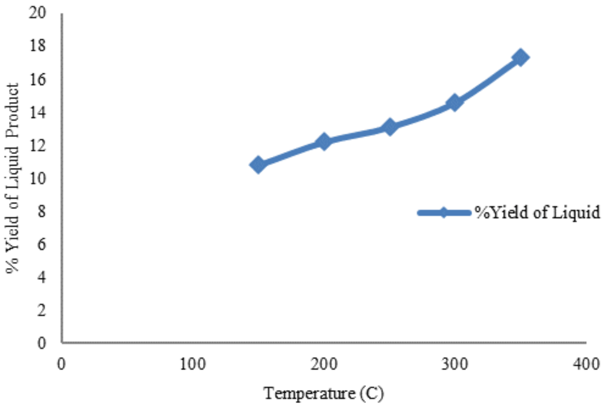

Figure 5. Effect of Various Temperatures Towards %Yield of Liquid Product

GC-MS (Gas Chromatography-Mass Spectrometry) Analysis

The overall quality of the product was linked to its composition. The main goal of this study was to create a liquid with similar properties to gasoline. After applying chemical parameters such as density, specific gravity, API gravity, and flash point to the product, it was determined that all of the products had a close resemblance to gasoline (as previously mentioned), but only two samples had their contents examined.

GC-MS instruments were used to determine the composition of the sample. The number and content of hydrocarbon components in the liquid product produced by catalytic cracking of polystyrene plastic waste were determined using a GC-MS instrument.

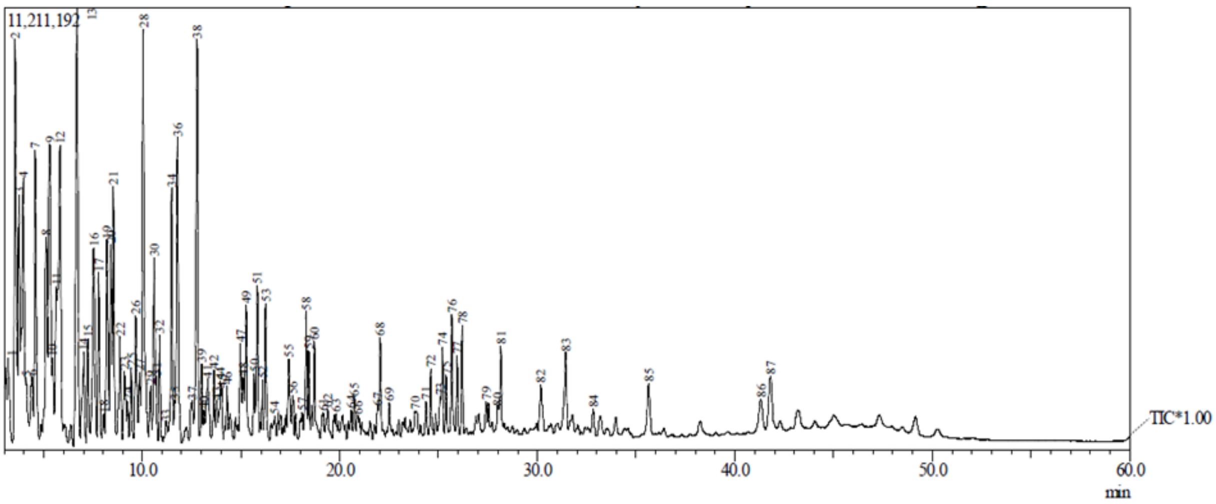

Figure 6. GC-MS Analysis Results for 60 minutes of cracking process, 250^{o}C and 4% of catalyst

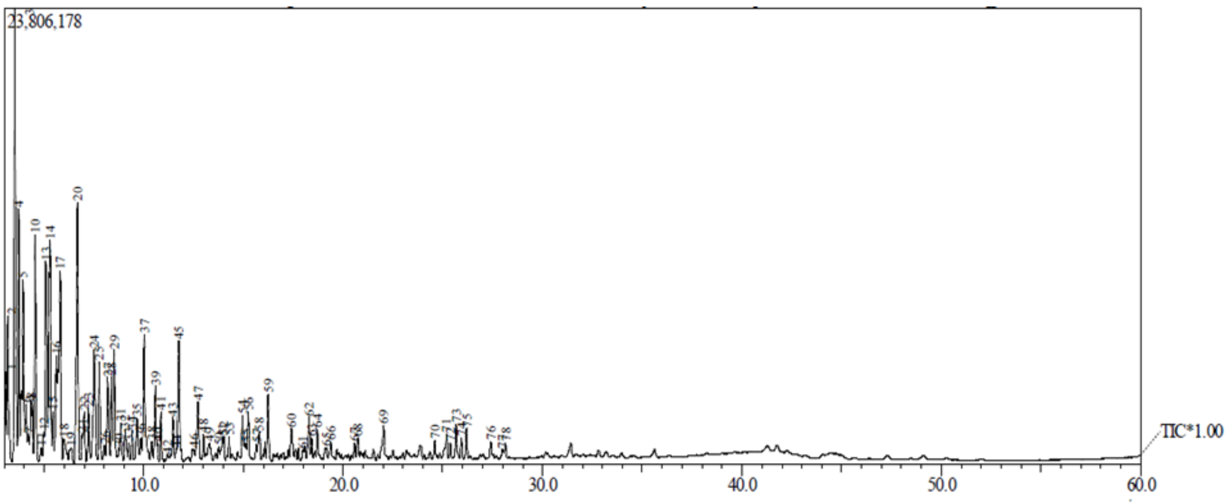

Figure 7. GC-MS Analysis Results for 60 minutes of cracking process, 350°C and 4% of catalyst

Figures 6 and 7 demonstrate how the liquid product incorporates alkane, alkene, toluene, naphtalene, and other components. Because it possessed the highest percentage of gasoline (C5-C12), the fewest other components, and a little amount of diesel, this liquid product was picked as the best of all the commodities (C13-C20). The high temperatures utilized in the procedure expedited the cracking of the raw material, resulting in a larger gasoline output. The best composition of the two samples was achieved using catalytic cracking with a 60-minute cracking interval, 350°C temperature, and 4% catalyst addition.

Conclusion

Polypropylene plastics waste conversion to liquid fuel by catalytic cracking using bentonite as catalyst experiment is intended to find the optimum condition. There are some factors to be considered to achieve that goal; among them are the use of catalyst and optimum operating condition. From the experiment conducted, it can be concluded that:

1. The variation of catalyst mass and cracking temperature influence the percent yield and percent composition of product.
2. The optimum conditions cracking of polypropylene plastics waste with bentonite as catalyst is at temperature of 350 °C with 4% catalyst mass or 20 grams.
3. The highest percent composition of C_6H_{14}, C_7H_{16} and C_8H_{18} in liquid product is 16.92%, 18.48%, and 12.22% respectively at temperature of 350 °C.

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References

[1] Mandeel, A.T., Abdul-Qader D. Faisal and Ibrahim J. Ibraheem., “Cracking of Plastic Wastes (PP, PET, and LDPE) for Liquid Fuel Production as Alternative Energy by Using Vacuum Pyrolisis Method”, College of Science, University of Technology, University of Anbar, 2013.

[2] Nindita, V., “Studi Berbagai Metode Pembuatan BBM dari Sampah Plastik Jenis LDPE Dan PVC Dengan Metode Thermal & Catalytic Cracking (Ni-Cr/Zeolit)”, *Teknis*, Vol. 10, no. 3, pp. 137–144, 2012, DOI: 10.32497/teknis.v10i3.231

[3] Priyatna, A. O., Zultiniar and Saputra, E., “Perengkahan Katalitik Limbah Plastik Jenis Polypropylene (PP) Menjadi Bahan Bakar Minyak Menggunakan Katalis Zeolit A” *JOM FTEKNIK,* Vol. 2, no. 2, 2015, Link: https://jom.unri.ac.id/index.php/JOMFTEKNIK/article/view/8044

[4] Hazrat, M. A., M. G. Rasul, and M. M. K. Khan, “A Study on Catalytric Cracking for Production of Clean Transport Fuel and Reducing Plastic Wastes”, 6th BSME International Conference on Thermal Engineering. *Procedia Engineering,* Vol. 105, pp. 865–

876, 2015, DOI: 10.1016/j.proeng.2015.05.108

[5] Raja, A. and Murali, A., “Conversion of Plastic Wastes Into Fuels”, *Journal of Materials Science and Engineering*, pp. 86-89, 2011, Link: https://www.semanticscholar.org/paper

[6] Wilczura-Wachnik, Hanna. Catalytic cracking of hydrocarbons (Theory and manual for experiment). Faculty of Chemistry, Chemical Technology Division, University of Warsaw. Poland (2010).

[7] Sharuddin, SD. Anuar, Faisal Abnisa, Wan MohdAshri Wan Daud, and Mohamed Kheireddine Aroua. Energy Conversion and Management.Department of Chemical Engineering, Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia (2016).

[8] Maddah, H. A., “Polypropylene as a Promising Plastic: A Review”, *American Journal of Polymer Science,* Vol. 6, no. 1, pp. 1-11, 2016, DOI: 10.5923/j.ajps.20160601.01

[9] Beyene, H. D., “Recycling of Plastic Waste into Fuels, A Review”, *International Journal of Science*, *Technology and Society*, Vol. 2, no. 6, pp. 190 – 195, 2014, DOI: 10.11648/j.ijsts.20140206.15

[10] Almeida, Débora and Maria de Fátima Marques., “Thermal and Catalytic Cracking of Plastic Waste”, Instituto de Macromoléculas Eloisa Mano, Universidade Federaldo Rio de Janeiro – UFRJ, Rio de Janeiro, RJ. Brasil, 2014, Link: https://www.academia.edu/31545754

[11] K.V, Sreejith., Ashique P.T, Abhijith B, and Mohamed Suaib, “Study on Plastic Recyling Using Cracking and Catalyst Cracking”, *International Research Journal of Engineering and Technology (IRJET)*, Vol. 2, no. 6, 2015, Link: https://www.irjet.net/archives

[12] Ahmed, Mehnaz Rumana. Effect of Recycling in Post-Consumer Polystyrene Cups. Degree Thesis Plastics Technology. Arcada (2016).