Production of Fuels from Nigeria's Untapped 'Waste Wealth' Using Pyrolysis.

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Adeola Grace OLUGBENGA[1], Temilorun Taiwo EGBEDAYO[2], Muibat Diekola YAHYA[3] and Mohammed Umar GARBA[4]
[1234]Department of Chemical Engineering, Federal University of Technology Minna.

Abstract. The extent of pollution that plastic waste poses to our environment is phenomenal. In Nigeria, millions of metric ton of plastics are manufactured continuously due to industrialization and urbanization, a measurable rise in the generation of waste plastics is inevitable, so also is the need to seek alternate energy sources in the place of conventional fuels. Oral disposal of plastics has led to blockage of drainages, flooding and several mess yet unemployment is very high. It is important to venture into how this solid waste can create job opportunities along recycling value chain. Plastics are made by polymerization of hydrocarbons. These hydrocarbon are of typically high molecular mass which are fuel based material. The catalytic and thermal pyrolysis of waste polyethylene terephthalate was carried out using a fixed bed reactor operating at a maximum temperature of 600^0C and 350^0C respectively. The product obtained are liquid fuel, char and gaseous fuels. For the latter, the catalyst to plastic ratio was effective for ratio 1:6 thus increasing the yield of gas from 50.7% to 55%. The liquid oil obtained in thermal pyrolysis has low quality compare to catalysis pyrolysis with high yield of 39%, but 30.5% for catalysis pyrolysis. The effect of catalyst on temperature, the retention time and product yield enhance the identification of the hydrocarbon compounds present in the liquid oil, ZSM 5 catalyst ratio was raised to ratio 1:10. About sixty-one compounds were identified and the quality of fuel oil was described in terms of aromatic and aliphatic hydrocarbon content. The direct implication is that the fuels can serve as alternatives to kerosene petroleum fuel fractions.

1. Introduction

The deficiencies and non-sustainable future stockpile, alongside ecological contamination produced by oral dumping of the plastic waste is detrimental to human health. It can be as pandemic as diseases if not properly curtailed [1-2]. Further, plastic stock pile are of ecological damage [3]. Renewable energy sources lsuch as the waste plastics can emerge the most reasonable reactant that produces wealth translating from waste to energy. Other possible renewable sources are solar, geothermal, wind, most waste of biomass which are pulling in noteworthy consideration attention to combat global warming. Regarding the span of consistent expanding energy demand with small and supply in Nigeria, it becomes urgent to pull into obtaining useful products from the waste [4]. For the plastic waste which is processed to produce petrochemical compounds, innovative technical processes, and cost effective techniques alongside governmental incentives can help to initiate and expand the development of sustainable energy source [5-6]. An added disadvantage is that achieving the natural decomposition of plastics may require billions of years. Equally, the ceaseless disposition of plastic in the landfill would negatively affect the environment. To defeat the impossibilities of recycling the thermoset plastics for example and overcome the requirements of arranging which is labour intensive, a sustainable and dependable strategy is built up by process handling. These days, converting the waste into valid asset has been a splendid engineering procedure to completely use the waste to satisfy the increased energy yaning. Plastic wastes can be transformed into important energy which are gotten

from petrochemical characterized as notable calorific value as an added advantage. The conversion can be made possible through several thermal treatments technologies such as plasma process, gasification, co-pyrolysis, pyrolysis and incineration [7]. The literature survennaice has indicated that pyrolysis is the most alluring among all current conversion means. This is due to the fact that the initial volume of the feedstock is well less than the energy recovered from the waste. More scientifically the waste requires lower disintegration temperature and low capital expense [8-9].

Deterioration is hard to achieve with even disposal with other municipal solid waste thus the fraction of plastics in this waste expands persistently with time. The need to utilized plastics materials is reasonable because it is cheap to assemble plastics, it is durable, lighter and flexible. Waste plastics are non-biodegradable material, constituting a negatively lasting effect on the environment. According to the statistics provided by [10], the absolute amounts of plastic waste generated has reached 280 million globally. Technologically, plastic waste can be transformed into alternative fuels by utilizing pyrolysis. Therefore, plastic utilization around the globe is expanding by 4% every year [11]. Generally, waste plastic consist of about 46% high and low density polyethylene (HDPE and LDPE), it consist of about 5% polyethylene terephthalate (PET), 5% acrylonitrile-butadiene-styrene (ABS), 7% polyvinyl chloride, 16% polypropylene, 16% polystyrene and 5% other polymers [12]. Attempt have been made to characterize the fuel from plastic waste based on the feedstock but the description of the yield of liquid oil from these feedstock is still a stiff challenge.

Pyrolysis can be said to be a disintegration chemical process that follow thermal and chemical route to decompose organic matter into carbon rich vapour within few minutes as opposed to the billions of years necessary for bio-degradation. The products from pyrolysis can be condensed into fluid product and the rest fraction are un-condensable [13]. The advantage of this conversion is that, from a low energy substance of solid waste, a high-energy content can be generated, these are the char, tar and gas. It was observed by [14] that 80% of feedstock heated at moderate temperature around 500^0C yielded a high measure of liquid oil. A flexible process is attainable because the process parameter can be changed as desired. This flexibility in turns allows the parameter to be optimized and hence the product yield which dependent on preference applications like furnaces, boilers, turbines are workable in any plastic paralysing processes. This is because, the conversion ratio of the products rely upon the condition of the process. This includes, the temperature which may be at the peak point, the pressure, and the catalyst volume [15].

Regarding the catalyst an example of a good one is the zeolite. This catalyst has a structure which comprises of tetrahedral unit of AlO_4 and SiO_4 that are interconnected through oxygen atoms. The function and activity of zeolite in catalyst are controlled by the measure of acid sites situated on the surface [16]. The scientific implication of using catalyst such as zeolite are because they contain active acid site and they have large surface area for reactions to occur these fact are also reported by [16]. Although, [16] indicated the basic techniques adopted during pyrolysis, namely thermal cracking, catalytic cracking, their research used four types of plastics and biomass as feedstock. Here, the thermal and catalytic cracking of plastic was carried out in a fixed bed reactor.

Despite the combined advantageous effect of waste plastic processing, the method of decomposition of polyethylene is yet to be fully understood. The advantageous effect is yet to the tapped by the Nigerian economy and this has thus necessitated this research. Based on the products yield and quality from experimental process, a good comparison is provided. In order to accomplish this aim the required objectives include; the decomposition of raw material. The effect of ZSM-5 zeolite catalyst on fractions of oil, gas and char was identified to provide information for upscale.

2. Methodology and Experimental Set up

A reactor (3Liters) having a close system that operate in the absence of oxygen and has the capacity to attain 700^oC was constructed. 200g of waste plastics were loaded into the reactor for heating; the temperature was raised from room temperature to 500^oC- 600^oC until this temperature range and retention time of 60 minutes was reached. The catalytic pyrolysis reaction was carried out by mixing the catalyst with the plastics, before loading into the reactor. The temperature ranges 350 to 400°C in the reactor and retention time of 40mins. The catalyst to feedstock ratio of 1:6 [17] the samples were melted and heated in the reactor, organic vapour was produced, these vapours enters the condenser and

were converted into liquid oil. The optimum condensation of vapours was attained when the condenser temperature was maintained at -3°C using iced water as coolant. The condensate was collected from the oil collector while the uncondensed gases came out and were exhausted outside free from oxygen. The gas mixture was cooled in the condenser and the desired product was obtained. The fractions of the oil, gases and char were weighed. The study included the effect of catalyst on the oil yield [18]. In order to increase the slurry liquid product yield while the char reduced. [19-20] were suggested. An optimum yield was carried out via the process flow in figure 1 after several preliminary tests.

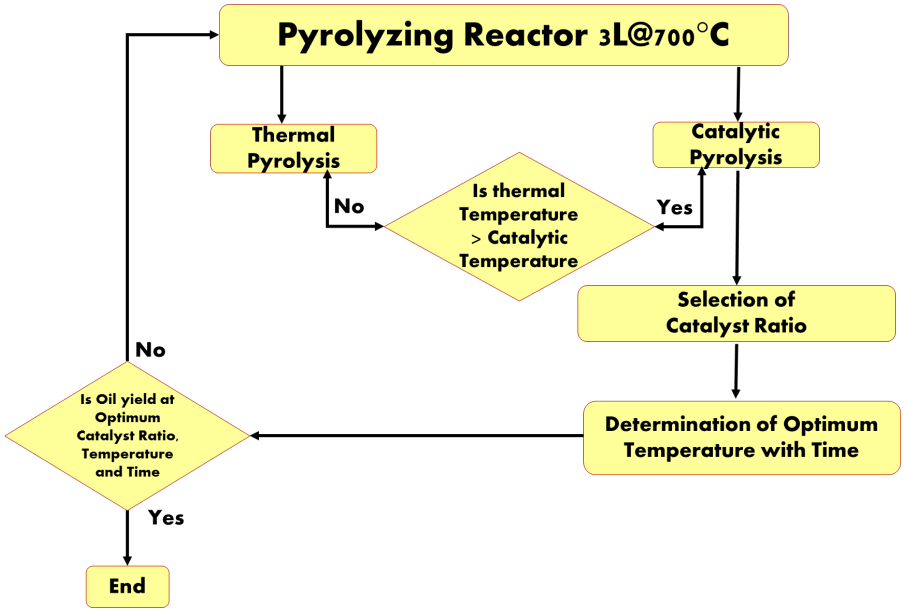

Figure 1. Block Flow Diagram for Optimum Product Yield

3. Results and discussion of results

Table 1 presents the yield from catalytic and thermal processes. It can be deduced that thermal pyrolysis produced more yield of liquid of (39%), yield of gas produced was 50.7%, and char of 10.25%. Although, catalytic pyrolysis decreased in liquid oil yields to 35% but increase in char yield is 14.5% and gas yield (55%). The difference in result is due to presence of catalyst. The temperature required for this product yield is 560 - 600°C for thermal pyrolysis while 350 to 400 °C is required for catalytic pyrolysis. This implies that there is a significant amount of energy saved for the catalytic option.

Table 1: Products obtained from pyrolysis of waste mainly polyethylene terephthalates complex

Pyrolysis products	Thermal pyrolysis products (gram)	Percentage yield (%)	Catalytic pyrolysis product (gram)	Percentage yield (%)
Wax-like (slurry liquid)	78	39	61	30.5
Char	20.5	10.25	29	14.5
Gas	101.5	50.7	110	55

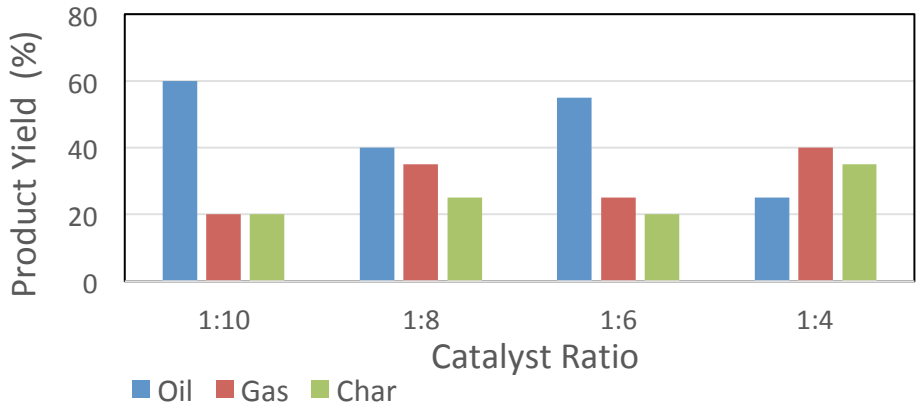

Figure 2. The Effect of Catalyst Ratio to Product Yield

3.1. The Effect of catalyst ratio on the oil

Figure 2 presents the effect of catalyst ratio on oil yield. For the peculiar combination of waste assembled and used as feedstock, the catalyst ratio is significant to the plastic oil. The plastic oil yield at ratio 1:10 and ratio 1:6 were probably the best combination for the mixed waste plastic combination used as feedstock. This two ratio were observed after several preliminary tests. Thus the implication is that there are compositions of plastic types in the feedstock that are responsive to a catalyst ratio 1:10 and 1:6 which are adequate proportion for this particular plastic combination which is mainly polyethylene terephthalates.

3.2. Effect of Temperature on Reaction Time

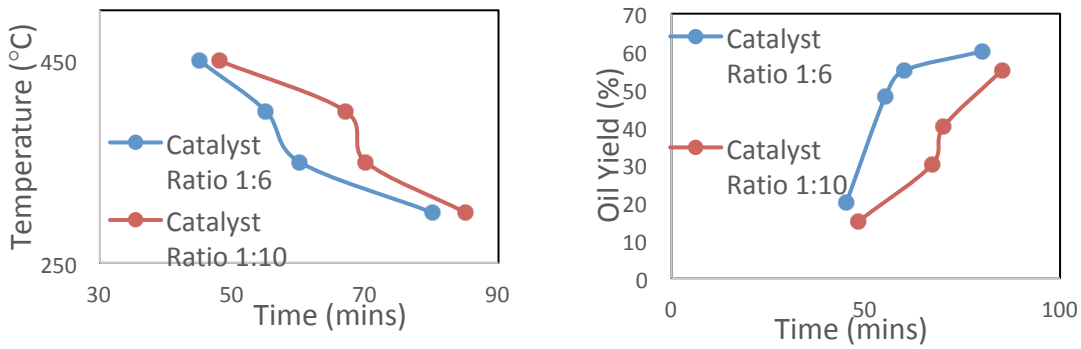

Figure 3. Effect of Temperature on reaction time (left) effect of catalyst ratio on the yield (Right)

Figure 3 presents the influence of the temperature on the reaction time. The temperature determines how long it will take to obtain the best yield of plastic oil. Catalyst ratio 1:10 has significant time gain of up to 10minutes at every temperature tested. At 300^{o}C a gain of 10minute at 350^{o}Ca gain of 20minutes at 400^{o}C a gain of 18minutes and at 450^{o}C a gain of 3minutees. There is an indication that the catalyst ratio is equally reasonable at 450^{o}C. Therefore it is necessary to further test the effect of temperature on the yield.

3.3. Effect of Catalyst ratio on the yield at process time

The ratio 1:10 gave a maximum yield of 60% after 80mins while catalyst to plastic ratio gave a yield of 55% after 88minutes. Observe from figure 3. The catalyst to plastic ratio 1:10 is of a better yield for every temperature tested. This is best observed based on the activity of the catalyst as an activator for

surface reactions. ZSM-5 zeolite catalyst have high BET surface of 412.0m^2/g (Lopez et al, 2011), the produced char was 14.5% with ZSM-5 and it is higher than 10.25% from thermal pyrolysis. In addition, gases produced were increased with ZSM-5 zeolite catalyst 55%. [21-23] indicated similar products yield. These researchers indicated that the use of catalyst reduced overall yield of liquid with high amount of char and gases generated. The reduction in yield of liquid and increment in generated gas for a catalytic pyrolysis with ZSM-5 was because of its meso-porous structure high BET surface area.

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3.4. Fuels and Application of Fuels Obtained from Waste Plastics

The plastic oil was characterized using gas chromatography - MS and the signature of the fractions indicated that hydrocarbon fuels such as gasoline, diesel, and aviation kero can be obtained by further refining of plastic processes.

[24-26] has shown that processed plastic oil can have similar octane rating as that of gasoline. The gasoline obtained from catalytic pyrolysis has been tested in power engine [25].

The type of catalyst used in the catalytic pyrolysis of plastics determines the fuel obtained for example, zeolites, beta, clinoptilolite, REY, USY, ZSM-5 and MCM-41, silica alumina has been used for obtaining gasoline [26]. The plastic oil obtained in this research is of the gasoline type of fuel. This is because the flash point is of gasoline. The ZSM-5 calatyst used converted the oil obtained to gasoline. The resulting fuel has influenced by the catalyst which have sufficient acid sites in the catalyst. When this sites increases in number, the level of the catalyst activity in polyolefin pyrolysis increases.

Also, zeolite possesses high acid strength therefore they enhance conversion than non-zeolitic catalysts. [25]. Some research obtained transportation fuel using HY. This was due to the conversion of polyethylene to the transport fuel. Where REY zeolite yielded the highest volume of gasoline with higher octane number. The REY is also characterized to contain large pores and coupled with an amount acidic strength thus, it is better. The octane rating reported for the gasoline obtained with Y zeolite and ZSM-5 zeolite yielded oil which was also high however the volume of gasoline was low using Y zeolite compared to REY this is because the decomposition of plastic by the ultra-stable-Y zeolite was lower in activity. Catalyst was studied by [27] and fuels were produced. The product test included ignition of the gas and application of the liquid in kerosene stove. A blue flame was observed during gas flaring and the liquid fuel was suitable alternative for kerosene.

4. Conclusion

Pyrolysis of plastic mixture which contain mainly of polyethylene terephthalate (PET) has been conducted to obtain fuel using ZSM-5 zeolite. The plastic mixture liquid production (wax-like) for thermal process required higher temperatures compared to catalytic pyrolysis process. The percentage yield of gas in both thermal and catalytic pyrolysis is dependent on the composition of waste plastics for waste plastics which contain PET half of the feedstock yield gases. In the plastic mixture production to fuel, a wax-life materials or product was formed and clogged into the pipe due to the large amount of PET probably present in the plastic mixture. ZSM-5 zeolite in contact with waste plastics yielded light yellow colour product fuel. The gas was obtained had blue flame which are indication of fuel contain present mainly light hydrocarbons compounds. Blue flame reduces environmental pollution. The methodology for fuel production create renewable energy which are repeatable. Thus pyrolysis is an effective technique for managing waste in Nigeria having a dual benefit production.

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