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Conversion of Low-Density Polyethylene (LDPE) and Mixed Low-Density Polyethylene with Polyethylene Terepthalate (LDPE and PET) into Hybrid Fuel

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research aims to provide the recycling techniques of low-density polyethylene (LDPE) and mixture of polyethylene terephthalate (PET) with low-density polyethylene (LDPE) waste. As a means of converting abundant waste to wealth, pyrolysis of LDPE and mixed LDPE - PET was

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carried out in a batch reactor made of stainless steel at temperatures between 450 – 460°C. The vapor produced from melting the waste was condensed to form the liquid hydrocarbon (fuel oil) product. The effect of reaction time and product yield were investigated. The physicochemical properties of the pyrolysis oil measured include density, specific gravity, flash point, color, fire point, flammability and viscosity. For the LDPE the flash point, fire point, density, specific gravity, and viscosity was found to be 39.5 °C, 48 °C, 8.1872, 0.793g/cm, 0.775g/cm^3, and 1.566 cSt respectively while for the Mixture of LDPE with PET the flash point, fire point, density, specific gravity, viscosity and Sulphur content was found to be 44 °C, 48 °C, 8.1872, 0.7837g/cm, 0.7916 g/cm^3, 1.1660 cSt and 8.1872 respectively. These values were found to be within the range of kerosene values. The fuel was tested in both kerosene lamp and petrol generator.

Keywords: Polymeric waste; hybrid fuel; low density polyethylene.

1. INTRODUCTION

"Polymeric wastes (plastics, sachet water bags etc) comprise a steadily increasing proportion of the municipal and industrial waste that is either poorly managed or accumulating landfills[1]. Household polymeric wastes mainly include materials which are made of polyethylene terephthalate (PET), high density polyethylene (HDPE), polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS) and polyurethane (PUR)[2]. The two most important of these polymers are PS and LDPE. Polystyrene (PS) is used for producing disposable plastic cutlery and dinnerware, CD, smoke detector etc,[3] low density polyethylene (LDPE) is used for production of plastic bags, containers, dispensing bottles, wash bottles, tubing, plastic bags for computer components and various molded laboratory etc".[4]

"Combating the menace of polymeric waste pollution has become a global environmental challenge leading to air, land, and water pollution [5]. Plastic pollution is capable of affecting land, waterways, drainage system, and oceans as a large percentage of marine and land creatures have died due to the fact that plastic is non-biodegradable and it causes hazards to soil [6]. It also emits toxic gasses when exposed or heated up [7]. It blocks drainage lines and fill up land space causing floods and erosion thereby causing deterioration of the Nigerian roads [8]. Plastics wastes are also harmful to human health; they may contain harmful acids which may lead to death [9]. Nigeria, which is the biggest oil exporting country in Africa, relies mainly on the proceeds of the oil trade for its GDP and based strategy in growing her economy [10]. However, with the declination of oil prices and increase in plastic wastes, the world is tending towards energy and sustainable development" [11]. Therefore, an urgent need for utilizing polymeric wastes into a solution for wealth creation is fundamental in Nigeria. As the wastes block the drainage lines and pipes, there is an enormous increase in mosquitoes, insects, bugs and many more which causes illness such as fever, cholera diarrhea and many more, and also results to deaths of aquatic and marine habitat [12].

"According to WHO, malaria, a disease caused by a parasite spread to humans through the bites of infected mosquitoes[13-16] this was caused by the wastes that are littered in the environment (especially polymeric waste) [17], mosquitoes kills more than 400,000 people yearly, mostly children in sub-Saharan Africa [18]. Malaria is endemic in Nigeria with about 53 million cases annually (one in four residents) and 81,640 deaths annually (nine deaths per hour) from the disease [19-20]. However, there is hope of ending malaria as a vaccine has been found to surpass the 75% efficacy goal set by the WHO for a malaria vaccine to receive a nod"[20-23].

2. MATERIALS AND METHODS

- The reactor and LPG burner was locally fabricated, gas cylinder, beakers, pipe wrench, thermometer was received from FUD Chemistry lab, LDPE and PET ware collected and sorted from waste dumps and street.

2.1 Pyrolysis of LDPE

The samples, discarded low density polyethylene (LDPE) wastes ware collected and sorted by handpicking municipal waste dumps and street litters across Dutse, Jigawa State, Nigeria. The samples were subjected to sample preparation where all dirt and unwanted substances like sand and mud were removed, the samples were cleaned by soaking for about an hour in water. They were thoroughly washed, sun dried for about five hours and shredded. About 2.5 kg of the sample (LDPE) was weighed and charged into the batch reactor. The reactor was connected to a condenser unit via a pipe, which is obliquely projected from the center of the cover of the reactor. The reactor was covered using gaskets and sealed with the aid of gasket seal to avoid leakage. The reactor was then placed on an LPG gas burner and heated. The sample was gradually heated using the pyrolysis method to a high temperature of 450-460°C under low pressure for 4 hours. As it undergoes thermal cracking, the bond started breaking and a foul smell was observed. When the temperature reached 100ºC, the pressure was released and steam started coming out, after about 45 minutes, the temperature rose to about 185°C, the pressure was released and the gas produced from the reactor was observed to begin condensing into a liquid phase using a condenser until the temperature reaches 460°C. About 250ml of pyrolytic liquid fuel (PLF) was recovered.

2.2 Pyrolysis of Mixed LDPE with PET

The samples, discarded low density polyethylene and polyethylene terephthalate (LDPE with PET) wastes were collected and sorted by handpicking municipal waste dumps and street litters across Dutse, Jigawa State, Nigeria. The samples were subjected to sample preparation where all dirt and unwanted substances like sand and mud were removed, the samples were cleaned by soaking for about an hour in water. They were thoroughly washed, sun dried for about five hours and shredded. About 3 kg of the sample (LDPE with PET) was weighed and charged into the batch reactor. The reactor was connected to a condenser unit via a pipe, which is obliquely projected from the center of the cover of the reactor. The reactor was covered using gaskets and sealed with the aid of gasket seal to avoid leakage. The reactor was then placed on an LPG gas burner and heated. The sample was gradually heated using the pyrolysis method to a high temperature of 450-460°C under low pressure for 4 hours. As it undergoes thermal cracking, the bond started breaking and a foul smell was observed. When the temperature reached 100ºC, the pressure was released and steam started coming out, after about 45 minutes, the temperature rose to about 200°C, the pressure was released and the gas produced from the reactor was observed to begin condensing into a liquid phase using a condenser until when the temperature reaches above 460°C. About 280ml of pyrolytic liquid fuel (PLF) was recovered.

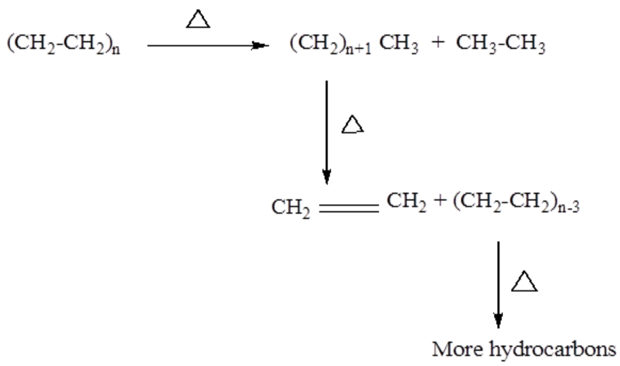

Fig. 1. LDPE degradation

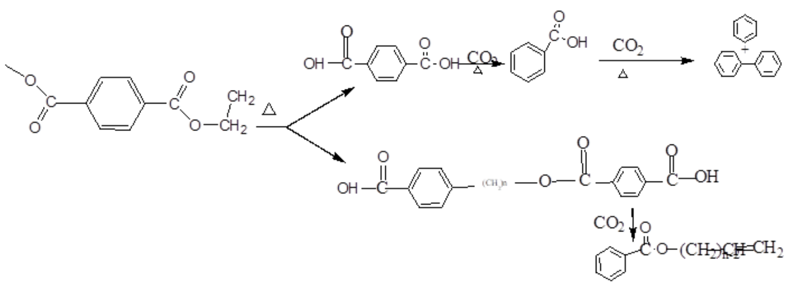

Fig. 2. PET degradation

3. RESULTS AND DISCUSSION

Table 1. Results of Digital Analysis of Pyrolytic Liquid Fuel Obtained from Low-Density Polyethylene (LDPE)

S/N	Properties	Observation/Average Value
1	Color	Slightly yellow
2	Odor	Obnoxious odor
3	Flammability	Flammable at room temperature
4	Flash point	39.5 ^oC
5	Fire point	42 ^oC
6	Density g/cm^3	0.793g/cm^3
7	Specific gravity g/cm^3	0.775g/cm^3
8	Viscosity cSt	1.566 cSt

Table 2. Result of physicochemical analysis on pyrolytic liquid fuel obtained from a mixture of LDPE with PET

S/N	Properties	Observation/Average Value
1	Color	Brownish yellow liquid
2	Odor	Obnoxious odor
3	Flammability	moderately Flammable at room temperature
4	Flash point	44 ^oC
5	Fire point	48 ^oC
6	Density g/cm^3	0.7837g/cm^3
7	Specific gravity g/cm^3	0.7916g/cm^3
8	Viscosity cSt	1.166 cSt

Table 3. Comparing physicochemical properties of pyrolytic liquid fuels (LDPE and Mixed LDPE with PET) with standards

S/N	PROPERTY	Mixed LDPE with PET	LDPE	Kerosine	Diesel
1	Flash point	44 ^oC	39.5 ^oC	38 ^oC	43 ^oC
2	Fire point	48 ^oC	42 ^oC	41 ^oC	46 ^oC
3	Density g/cm^3	0.784g/cm^3	0.793g/cm^3	0.794g/cm^3	0.851g/cm^3
4	Specific gravity g/cm^3	0.791g/cm^3	0.775g/cm^3	0.843g/cm^3	0.893g/cm^3
5	Viscosity cSt	1.166 cSt	1.566 cSt	1.389 cSt	2.544 cSt
6	Flammability	Flammable	Flammable	Flammable	Flammable
7	Color	Brownish Yellow	Brownish Yellow	Slightly Yellow	Brownish Yellow

Table 2 above shows the properties of the pyrolytic liquid oil from a mix of PET-LDPE waste can be said to be a fuel. To authenticate this claim (fuel properties to know its usability as an engine fuel), the physicochemical properties were compared with those of standard kerosene and diesel in Table 3 below.

Physicochemical properties of standards were carried out in the laboratory using diesel and kerosene obtained from Azman filling station along BUK road, Kano Nigeria.

4. DISCUSSION

The study of the production of liquid fuel oil from low-density polyethylene (LDPE) and mixed low-density polyethylene and polyethylene terephthalate (LDPE with PET) wastes via a pyrolysis melted at a temperature between 450-460°C has been conducted. Each experiment run time temperature was monitored properly to prevent overheating of the reactor. In the initial state of the experiments, the temperature profile rose from 170-300°C to melt the solid waste sample. When the initial waste sample melted, the first vapor production took an extra 45 minutes in each experiment. It was found that optimum and expected production captured is between 185-200°C. The maximum production temperature to give optimum yield margin rose to 460°C. Once a sample finishes, the experiment shuts-down and was allowed to cool for 15 minutes. Subsequently the fuel oils produced were allowed to cool. The heat combustion properties of the fuels produced were compared using the properties of standard fuels. Also, flash point, density, specific gravity, fire point, color, and viscosity analysis were carried out and compared with those of standard kerosene and diesel.

4.1 Physical Analysis of the Products

The preliminary tests on the produced liquid fuel have shown that, for LDPE density is 0.793g/cm^3 and mixed LDPE-PET density is 0.7837g/cm^3, which falls within the range of standard kerosene density, 0.78 - 0.81g/cm^3. The flash point of LDPE and mixed LDPE with PET were found to be 39.5 ^{o}C and 44 ^{o}C respectively, which falls within the range of kerosene flash point, 38 - 52 ^{o}C. The specific gravity of mixed LDPE with PET and LDPE from the table above were found to be 0.7916g/cm^3 and 0.775g/cm^3 respectively. which are closer to the true value of specific gravity for kerosene, 0.786g/cm^3. The viscosity of mixed LDPE with PET and LDPE were found to be 1.1660 cSt and 1.566 cSt, but judging from the value of viscosity for kerosene from the table above, it is safe to say that the pyrolytic liquid fuel is more viscous than the standard kerosene. From the result above, we can say that the pyrolytic liquid fuel is is a hybrid fuel of kerosene and other byproducts.

5. CONCLUSION

This research aims to provide the recycling techniques of LDPE and mixture of PET with LDPE waste. As a means of converting abundant waste to wealth, pyrolysis of low-density polyethylene and mixed LDPE with PET was carried out in a batch reactor made of stainless steel at temperatures between 450 – 460^{O}C. The vapor produced from melting the waste was condensed to form the liquid hydrocarbon (fuel oil) product. The effect of reaction time and product yield were investigated. The physicochemical properties of the pyrolysis oil measured include density, specific gravity, flash point, color, fire point, flammability and viscosity. From the results discussion, we can say that the pyrolytic liquid is a hybrid fuel of kerosene and some other byproduct will be determine in further research. The hybrid fuel was tested in a kerosene lamp and a petrol generator.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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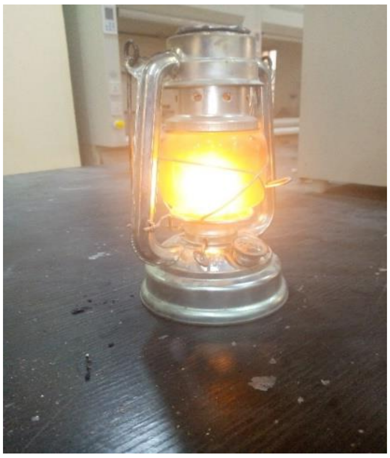
APPENDIX



Pictures taken during the research process at chemistry laboratory Federal University Dutse, Jigawa State, Nigeria

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