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ON ROAD EMISSION TEST IN A 4-STROKE BIKE USING WASTE PLASTIC DERIVED OIL

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ABSTRACT

Waste plastic oil has been obtained by degradation of broken bucket and tub made HDPE, saline bottles made of LDPE and polythene bags made of LDPE using fly ash as a catalyst. Oil boiling within 150^{0}C has been separated using a separation unit. The fraction termed as waste plastic petrol oil (WPPO) has been tested for its suitability as a substitute for petrol on a bike. The results suggested that WPPO from the waste plastic can be used as the substitute for petrol.

KEYWORDS: HDPE and LDPE Have Been Successfully converted into Hydrocarbons

INTRODUCTION

Our energy requirement is increasing day by day. Automobiles need liquid fuels like petrol or diesel for their running. Ships and aeroplanes also need liquid fuels. Gaseous fuel is largely used for cooking. Gaseous fuels are used in automobiles also. All these fuels are hydrocarbons.

Use of plastic also is increasing day by day. This generates a huge amount of waste plastic. Waste plastic consists of polythene bags used for packing food items, polythene bottles used for packing cleaning agents and medical accessories such as syringes.

Landfilling and incineration are the methods generally used for managing waste plastic. Landfilling requires a lot of space. Incineration is a process of burning waste plastic in the open atmosphere.

During burning the carbon in the waste material is largely converted to CO_2 which can be converted to carbohydrates by plants through photosynthesis. However, combustion will not take place to the complete extent. Incomplete combustion will produce smoke and emission of toxic chemicals like CO. Also during combustion nitrogen in the air and the organic material will combine with oxygen to produce NOx (NO and NO_2). Sulpher present in the waste materials will combine with oxygen to produce SOx (SO_2 and SO_3)

The burning of waste plastic also produces carcinogenic materials like dioxin. The boiling point of water and dioxin are nearly the same. So it can easily mix with water and may be consumed by humans and animals. This causes a lot of health hazards. Harmful effects of dioxin have been well described by Nobuomatsuura *et al.,* [1].

In order to manage the twin problems of waste plastic and fuel requirement plastic has been converted into liquid hydrocarbons which can be used to run automobiles by mixing it with auto fuels at a proportional ratio. Waste HDPE and LDPE have been successfully converted into hydrocarbons. Waste domestic plastic also has been converted into hydrocarbons. [2-33]

Degradation of waste plastic generates a large amount of liquid and gaseous hydrocarbons. The gaseous hydrocarbons can be used as a domestic fuel. The liquid product consists of hydrocarbons with a wide range of boiling points. The physical properties of relatively high boiling hydrocarbons have been found to be comparable to those of diesel and hence can be mixed with commercial diesel and used. Low boiling hydrocarbons can serve as a substitute for petrol. This paper reports about the suitability of using the low boiling hydrocarbons, obtained by degradation of waste plastic, as a substitute for petrol.

MATERIALS AND METHODS

Plastics**:** Unused waste HDPE, LDPE and polythene bags are shown in Figure. 1 is used for conversion it into liquid hydrocarbons. Big pieces of HDPE and LDPE plastics are cut with the help of cutting machine. Big polythene bags were cut in small pieces by using scissors.

Catalyst: Fly ash from the thermal plant at near places is used as shown in Figure. 1. The fly ash contains Si (Silicon), Al (Aluminium) and O (oxygen), Silica (SiO_2). Silica plays a vital role in the degradation of plastics since it can be used as a catalyst.

HDPE **LDPE** **Polythene bags** **Fly ash**

Figure 1: Photographic View of Waste Plastics and Catalysts

DESCRIPTION OF THE REACTOR PLANT

Figure 2: Photographic View Reactor Plant

The photographic view of the reactor used for catalytic conversion is shown in Figure. 2. The reactor is a cylindrical vessel made up of stainless steel with a diameter of 1300 mm. The reactor is surrounded by a thin cylindrical sheet.Glass wool is placed in between the reactor vessel and the thin sheet. The glass wool acts as an insulator. The top of the reactor is provided with a safety valve, a pressure gauge, an inlet with an airtight stopcock for feeding the waste plastic and an outlet which is connected to the water cooled condenser. The safety valve withstands the pressure up to 500 kg/m^2. A hand hole is provided with an airtight stopcock at the bottom of the reactor to remove the materials after cracking. A thermocouple is placed at the bottom of the reactor to measure the temperature inside the reactor. An LPG burner is provided at the bottom of the reactor attached to a jack. Jack is used to increase or decrease the height of the burner. This is used to control the temperature inside the reactor.

This burner is attached to an LPG gas cylinder using a hose.

Procedure for Mixing the Waste Plastic and Catalysts

The plastic was washed with water to remove any dust and dirt particles. Then it was dried in the sunshine. A weighed quantity of the dried waste plastic and the lignite fly ash (which acts as the catalyst) were premixed in a tray. A small quantity of water was sprayed on the mixture of plastic and catalyst. This was done to prevent the flying of fly ash to the atmosphere and to give a binding between the fly ash and the plastic. After thorough mixing of the mixture, the mixture was dried in air to remove the moisture.

Figure 3: Photographic View of Mixing the Catalyst

Degradation Process

Figure 4 shows the schematic diagram of a degradation plant. The burner was ignited using a lighter. When the burner burnt the temperature inside the reactor increased and the plastic got melt. As the temperature increased the plastic melt and cracking took place. The vapor formed due to the cracking of the plastic was passed through the water cooled condenser. The condensable vapor condensed into a liquid which was collected in the collecting tank. The amount of oil obtained was noted.

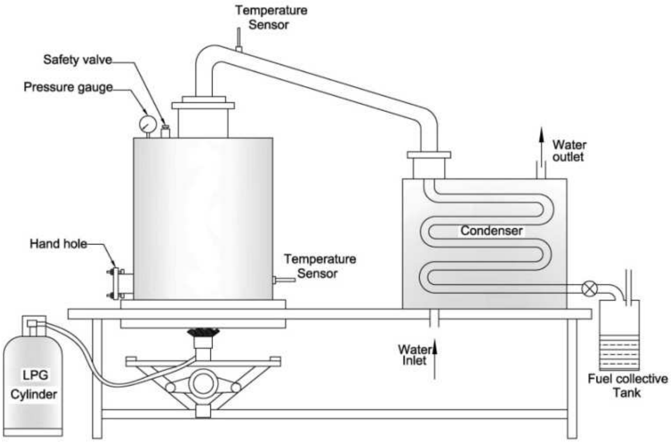


Figure 4: Schematic Diagram of Reactor Plant

System for Separating the Low Boiling Hydrocarbon from the Plastic Oil

The separating unit consists of the cylindrical vessel made up of stainless steel with a diameter of 1100 mm. This cylindrical vessel is surrounded by another stainless steel cylindrical vessel of diameter 1300 mm. In between these two cylindrical vessels silicone oil is placed. An electrical heating coil is immersed in the silicone oil. This entire setup is insulated by glass wool and a metallic sheet which surrounds the glass wool.

Figure 5: Low Boiling Hydrocarbons Separating System

The top of the cylindrical vessel is fitted with a pressure relief valve, pressure gauge, waste plastic oil inlet with an airtight closing knob, thermocouple and an outlet which is connected to the water cooled condenser.

The right side of the cylinder was fitted with a thermocouple to measure the temperature of the silicone oil. The left side of the separating unit is fitted with a glass tube to indicate the level of the silicone oil. The bottom of the separating unit is fitted with a slag drain to remove the oil remaining after the removing the low boiling hydrocarbons. There is also a control panel to stop the heating when the separating unit reaches a particular temperature.

Procedure for Separation of Low Boiling Hydrocarbons

The oil obtained by degrading the HDPE, LDPE and polythene bags was subjected to separation of the low boiling hydrocarbons using the separating unit described above. The separation was done taking 1000 mL of plastic oil.

The plastic oil was poured through the inlet of the separating unit. After pouring the oil, the valve was closed tightly. In the control panel, the temperature was set for collecting only fraction boiling within 150 °C. After checking the silicone oil level and the flow of water in the condenser the electrical heater was switched ON. As the coil got heated the heat was transferred to the silicone oil that leads to a rise in temperature of the silicone oil. Increase in the temperature of the silicone oil also increased the temperature of the plastic oil.

As the temperature rose the plastic oil vaporized and the vapor was passed into the water cooled condenser. In the condenser, the vapor was converted into a liquid. This oil was collected in a jar.

Preparation of Fuel

The fuel was prepared by collecting all low boiling fractions from HDPE, LDPE and polythene bags were mixed in the ratio 1:1:1 by volume. The properties were tested and compared with petrol. The resultant mixture was tested on the test bike.

Table 1: Properties of Fuel

Properties	Standard Petrol	Waste Plastic Oil
Density at (kg/m^3)	784	778
Boiling range	62-160 °C	45-150 °C
High Calorific value (MJ/kg)	45.7	46.1
Kinematic viscosity (cSt)	5.2	5.7

Engine and Instruments used for Conducting Emission Test

The experiment was conducted on a Yamaha SZ-RR bike with four strokes. The specifications of a bike are given in Table 2.

Table 2: Specifications of the Bike

Model	Yamaha SZ-RR
Displacement	149 cc
Max. power	11.9 bhp @ 7500 rpm
Maximum torque	12.8 Nm @ 6000 rpm
Bore	57 mm
Stroke	57 mm
Valves per cylinder	2
Fuel	Petrol
Cooling system	Air cooled

AVL di-gas analyzer was used to measure the exhaust gas emission. A separate plastic tank was arranged in the bike for measuring fuel consumption. A 12V battery was used to power the di-gas analyzer.

Procedure for Conducting the Emission Test in Bike Engine

Figure 6: AVL Di-Gas Analyser Fitted in Test Engine Exhaust Silencer

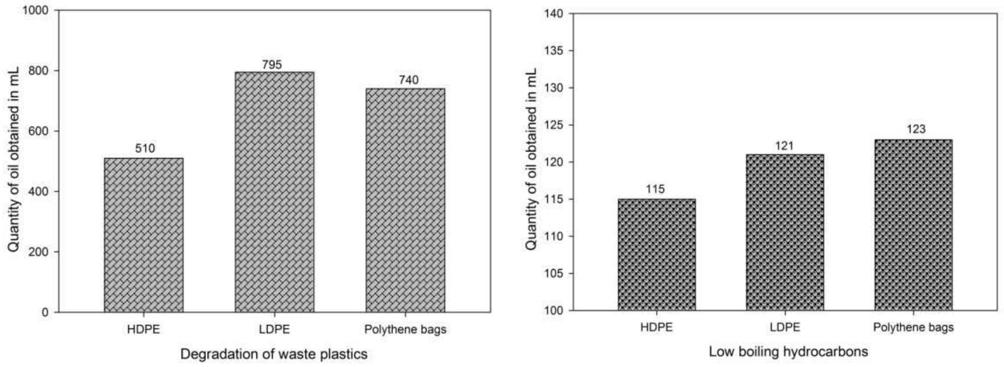
Figure 6 shows the experimental setup in phase I. The experiment was carried out in two phases. In phase I the experiment was conducted when the vehicle gear was at neutral. The emission such as CO, CO_2, NOx, and HC were measured by varying the engine speed by increasing the fuel supply with the help of an accelerator. The speed of the engine was varied from 2000 – 5000 rpm. At each speed, the engine was run for one minute. After running the engine for half minutes the AVL di-gas analyzer probe was inserted in the exhaust silencer and the emission readings were noted. The fuel consumption at each speed was noted for one minute. The emission test was carried out for waste plastic oil and petrol. The results are compared.

In phase II AVL di-gas analyzer probe was fitted in the exhaust silencer. The battery supply was given to AVL di-gas analyzer. The readings are taken when the vehicle was geared and run at a constant speed for one kilometer and the emission was tested after the vehicles complete half kilometer. This experiment was conducted on a ground without any traffic and other interference.

RESULTS AND DISCUSSIONS

Degradation of Plastic

Degradation of HDPE, LDPE and polythene bags was carried by taking one kg of plastic with 100 g catalyst. From the Figure 7 (a) it is seen that HDPE waste plastic produced 510 mL of oil, LDP produce 795 mL of oil and polythene bags produced 740 mL oil.



(a) (b)

Figure 7: Quantity of Oil Obtained by Degradation and Deriving of Low Boiling Hydrocarbons

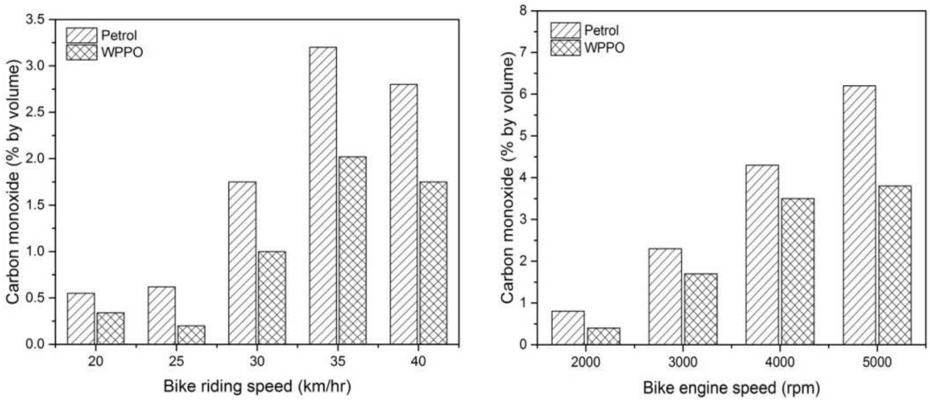
Deriving of Low Boiling Hydrocarbons from Waste Plastic

The quantity of low boiling hydrocarbons for each plastic oils is shown in Figure. 7(b). From the Figure 6(b) it is seen that the production of low boiling hydrocarbons from HDPE is 115 mL, LDPE is 121 mL and polythene bags 123 mL.

Emission Test

CO Emission

Comparison of CO emission for WPPO with petrol is shown in Figure. 8. Figure. 8(a) and 8(b) shows the emission of CO when the vehicle is running and the vehicle engine is running. CO emission is produced due to incomplete combustion of fuel in the engine and strongly depends on air-fuel ratio. As air-fuel decreased CO emission will increases. From the Figure 8(a) it is seen that the CO emission is low for WPPO when compared to petrol at all the speeds. This is due to the low viscosity of the fuel. Due to this the carburetion process for waste plastic oil is increased. Due to this, more number of oxygen molecules is present in the air-fuel ratio. This produced less CO emission when compared to petrol. From the Figure 8,(b) the emission CO is less than petrol due to the low viscosity of the fuel.

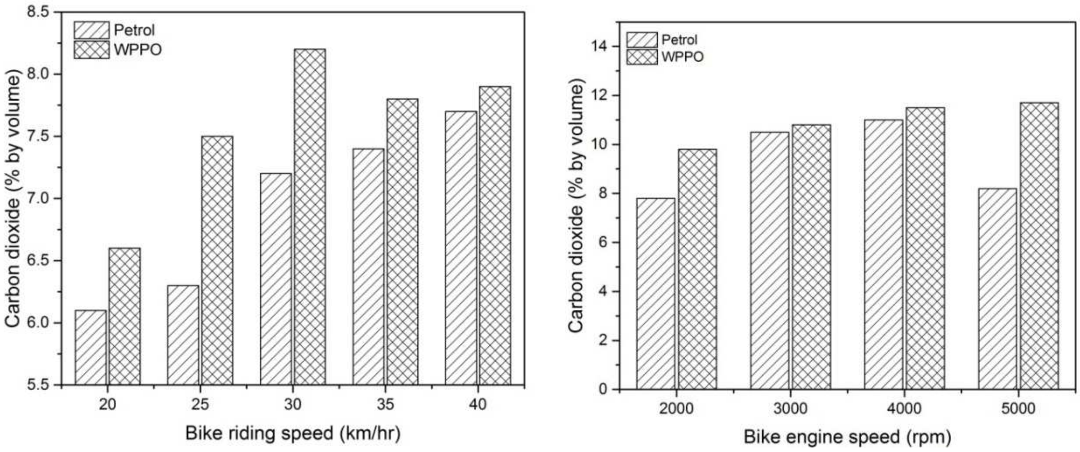


(a) **(b)**

Figure 8: Variation of Carbon Monoxide

CO_2 Emission

Comparison of CO_2 emission for WPPO with petrol is shown in Figure. 9. Figure. 9(a) and 9(b) shows the emission of CO_2 when the vehicle engine is running and the vehicle is running. CO_2 is a product of complete combustion due to sufficient amount of air in the air-fuel mixture and plenty of time in the cycle for completion of combustion process of fuel in the combustion chamber of the engine. From the Figure 9(a& b) it is seen that CO_2 produced is more in the exhaust. This is because of efficient combustion occurs due to high oxygen content due to high air-fuel ratio.

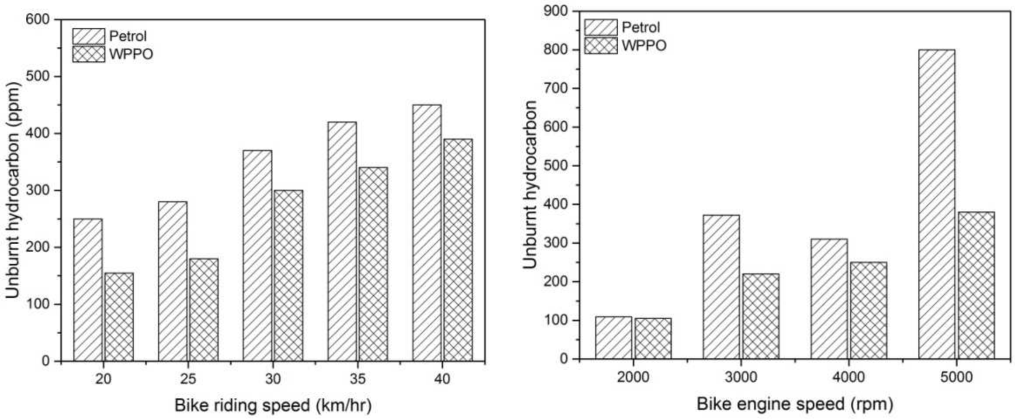


(a) **(b)**

Figure 9: Variation of Carbon Dioxide

HC Emission

Comparison of HC emission for WPPO with petrol is shown in Figure. 10. Figure. 10(a) and 10(b) shows the emission of HC when the vehicle is running and the vehicle engine is running. HC emission in an SI engine may happen due to incomplete combustion and flame quenching. From the Figure. 10(a) it is seen that HC emission is low for WPPO when compared to petrol. This is due to the increase in the air-fuel ratio. The oxygen molecules present in air-fuel mixture is sufficient to burn the hydrocarbons in the combustion chamber at a maximum extent. So the HC emission is low when compared to petrol. When the speed of the vehicle is less the combustion is lest. Due to this combustion occurs more effectively and in turn, low emission is produced. As the speed of the vehicle increased the HC emission also increased. The same trend is also seen in Figure 10(b).

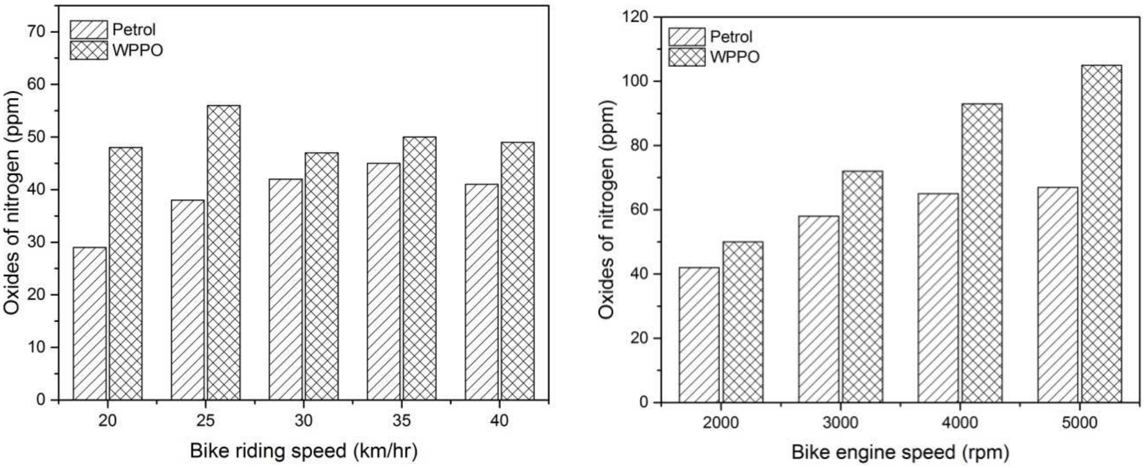


(a) (b)

Figure 10: Variation of Unburnt Hydrocarbon

NOx Emission

Comparison of NOx emission for WPPO with petrol is shown in Figure. 11. Figure. 11(a) and 11(b) shows the emission of NOx when the vehicle is running and the vehicle engine is running. The production of NOx in the combustion chamber is due to the operating of engine at the stoichiometric air-fuel ratio. The time of flame propagation is very less and the heat inside the engine will not get time to dissipate. From the Figure. 11(a) it is seen that the NOx emission is higher for the all the speed of the vehicle when compared to petrol. This is due to the burning of more hydrocarbon molecule with the support of more oxygen molecules present in the air-fuel mixture. The Figure. 11 (b) show the same trend.

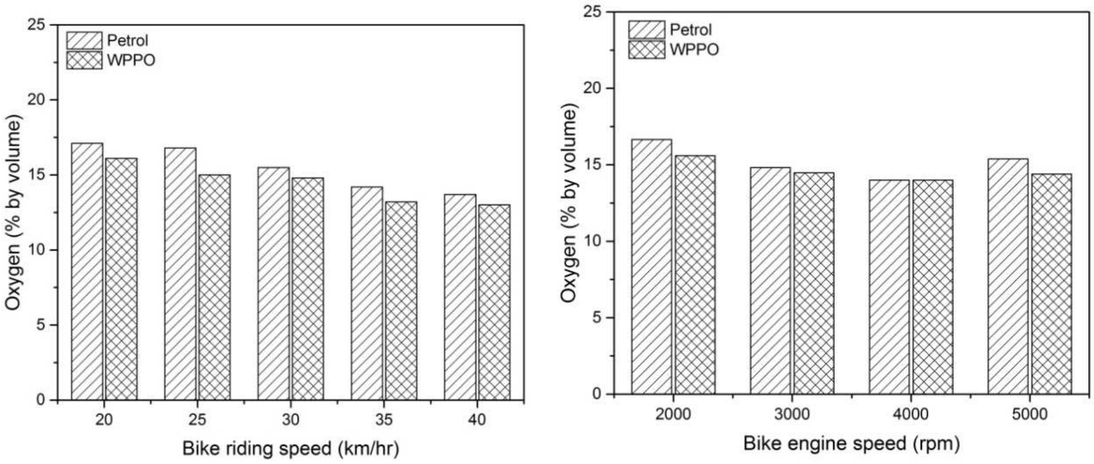


(a) (b)

Figure 11: Variation of Oxides of Nitrogen

Oxygen

Comparison of Oxygen for WPPO with petrol is shown in Figure. 12. Figure. 12(a) and 12(b) shows the percentage of oxygen content in the exhaust when the vehicle is running and the vehicle engine is running. From Figure. 12 it is seen that the oxygen percentage is low for the WPPO when compared to petrol. This is due to the amount of oxygen molecule burnt in the combustion chamber when the WPPO is used as fuel.



(a) (b)

Figure 12: Variation of Oxygen

All the emissions are within the permissible limit. Hence, WPPO can be used as a substitute for petrol.

CONCLUSIONS

Low boiling fraction has been obtained from the waste plastic oil formed by degradation of waste plastic. This low boiling fraction termed as WPPO (Waste paste petrol oil) and can be used as a substitute for petrol for running bikes.

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