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Waste Management By Pyrolysis

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Abstract: Waste management is a major problem faced around the globe of which plastic disposal is very difficult. Many of the currently used techniques have its own drawbacks when studied in the aspect of pollution. Pyrolysis is an innovative technique to safely dispose plastic as well as biomass and obtain liquid distillates that can be refined as fuels without causing much pollution problems. The work aims describes the properties of liquid distillate obtained from the pyrolysis process of various plastic and also from biomass pyrolysis using teak wood and co-pyrolysis of teakwood and high density polyethylene.
Keywords: Biomass, plastic, pyrolysis, waste

I. INTRODUCTION

With the growth of human civilizations, the consumption of resources are ever increasing, same is the situation with waste . Each year more and more waste is generated and only small portion of these subjected to recycling. The other common methods adopted for managing these waste are land filling and incineration. But these processes have their own disadvantages. Land filling of untreated waste can result in the release of harmful chemicals into the soil and incineration results in the release of toxic gases into the atmosphere. Pyrolysis is an effective waste treatment method that is capable of a wide variety of waste, both plastic and biomass.

Pyrolysis is a thermal degradation in an oxygen deprived condition. when plastic is subjected to pyrolysis it undergoes extensive breaking in its polymer chain and forms mixture mixture of different simpler molecules, most of which are condensable and can be extracted as liquid fuels and rest are obtained as gaseous fuel. Pyrolysis in wood is possible because of its main constituents like cellulose, hemicelluloses and lignin, which are essentially polymers and can undergo thermal cracking to simpler molecules.

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II. EXPERIMENTATION

A. Plastic Pyrolysis

HDPE, LDPE, PP and PS are all hydrocarbons consisting entirely of carbon and hydrogen, which are similar to hydrocarbon fuels such as liquefied petroleum gas (LPG), petrol and diesel. The pyrolysis reaction consists of three progressive steps: initiation, propagation, and termination. Initiation reaction cracks the large polymer molecules into free radicals. The free radicals and the molecular species can be further cracked into smaller radicals and molecules during the propagation reactions. At last, the radicals will combine together into stable molecules, which are termination reactions.

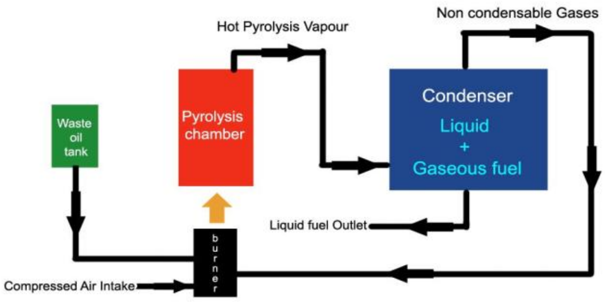
There are three types of cracking of the polymers: random cracking, chain strip cracking, and end chain cracking. The major cracking on the polymer molecular backbone is random cracking. Some cracking occurs at the ends of the molecules or the free radicals, which is end chain cracking. Some polymers have reactive functional side group on their molecular backbones. The functional groups will break off the backbone, which is chain strip cracking. The theoretical energy requirement to perform pyrolysis of 1kg PE is 1.047 MJ. The estimated calorific value of the products is about 43.3 MJ/kg. Therefore, the energy profit is very high for this process.

B. Biomass Pyrolysis

At around 160°C the removal of all moisture (dehydration) is complete. Over the temperature range 200°C to 280°C, all the hemicelluloses decomposes, yielding predominantly volatile products such as carbon dioxide, carbon monoxide and condensable vapors. From 280°C to 600°C the decomposition of cellulose picks up and reaches a peak around 320°C. The products are again predominantly volatiles. The decomposition rate of lignin increases rapidly at temperatures beyond 320°C. This is accompanied by a comparatively rapid increase in the carbon content of the residual solid material.

III. APPARATUS

The apparatus consists of a pyrolysis chamber of 25 liter capacity and square cross section made of mild steel plates. This is where the pyrolysis reaction takes place. The chamber has a lid which can be sealed after removing oxygen from the chamber before heating. The heat for the system is supplied using waste oil burner that utilizes waste cooking oil and compressed air. The use of waste oil burner significantly brings down the processing cost. The burner aids in attaining chamber temperature range of 600-700 degree Celsius within 5 minutes. The waste oil is stored in a tank attached near to the chamber. The hot vapors coming out of the chamber are passed into air cooled condensation chamber, where the vapor comes in contact with internal fins. The condensable fraction is turned into liquid fuel and non-condensable fraction is taken out and circulated to the burner. Batch processing method is utilized in the process where about 2 kg of waste feedstock is processed at a time.



IV. EXPERIMENTAL PROCEDURE

Batch wise processing is done. In each batch, 2 kg of waste is taken and pyrolysis is conducted for 60 minutes in the temperature range of 600-700 degree Celsius. The non-condensed gas from condenser is fed into the burner. The following batches are used for the study:

- Polyethylene (PE) and Polypropylene (PP)
- High Density Polyethylene (HDPE)
- Polyethylene terephthalate (PET)
- Polystyrene (PS)
- Teak Wood shavings
- Teak wood shavings and HDPE (1:1)

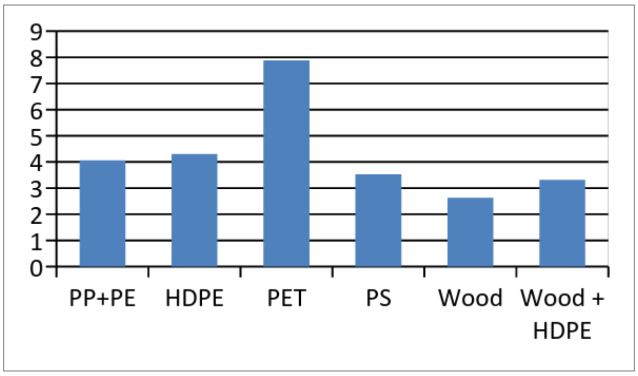
After completing 60 minutes of processing the residue left is taken out and weighed. This is to assess the speed with which various waste get cracked. And the fuel obtained is tested for viscosity flash point, density, liquid fuel yield. The colour of the fuel is also noted.

V. RESULTS AND DISCUSSIONS

A. Viscosity

Viscosity is measured using redwood viscometer with glass bulb of 50ml.

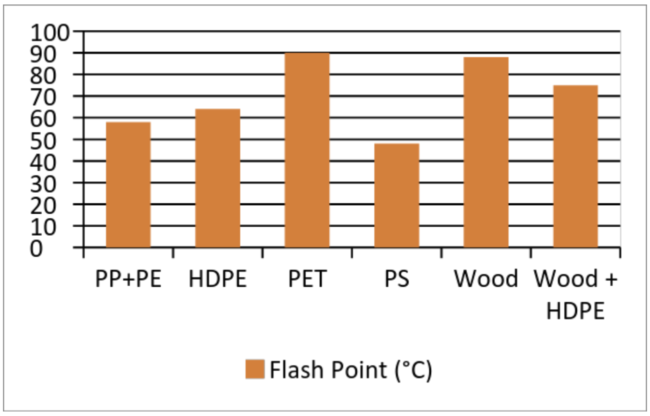
Viscosity (mm^2/sec)	**Fuel Source**
4.062	PP+PE
4.308	HDPE
7.887	PET
3.532	PS
2.633	Wood
3.313	Wood + HDPE



B. Flash Point

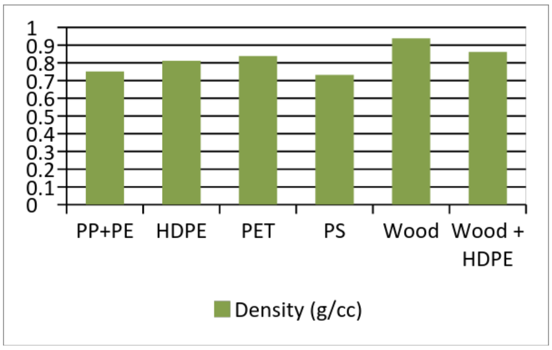
Flash point is measured using Pensky Marten closed cup tester

Flash Point (°C)	Fuel Source
58	PP+PE
64	HDPE
90	PET
48	PS
88	Wood
75	Wood + HDPE



C. Density

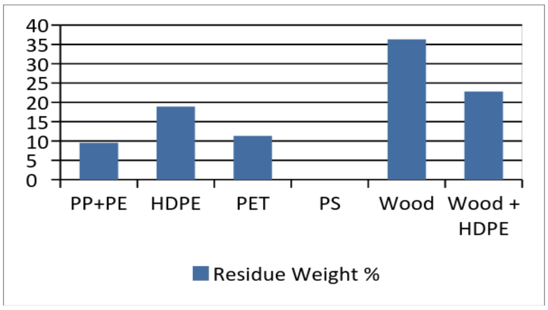
Density (g/cc)	Fuel Source
0.751	PP+PE
0.812	HDPE
0.838	PET
0.732	PS
0.938	Wood
0.862	Wood + HDPE



D. Residue Weight

The residue that is present inside the chamber after conducting 60 minutes of pyrolysis is taken out and weighed. It is a measure of efficiency of the pyrolysis process in managing different waste. The initial weight of every batch is 2Kg.

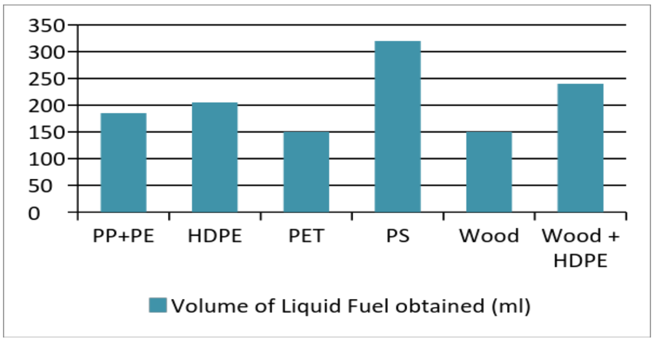
Residue Weight Percentage %	Residue Weight (grams)	Waste Material Type
9.5	190	PP+PE
18.9	378	HDPE
11.3	183	PET
0	Nil	PS
36.3	726	Wood
22.8	456	Wood + HDPE



E. Liquid Fuel Yield

By performing pyrolysis, only a small portion of the total fuel is obtained as liquid fuel and rest is obtained as gaseous fuel. The fuel that gets condensed in the condenser is poured into a measuring cylinder for getting the volume and the observation is

Volume of Liquid Fuel obtained (ml)	Waste Material Type
185	PP+PE
205	HDPE
150	PET
320	PS
150	Wood
240	Wood + HDPE



VI. CONCLUSION

From the tabulated observations, it can be observed that no residue was left in the chamber after performing the pyrolysis in case of PS while the other batches had sufficient residue. There is significant volume reduction when compared to initial feedstock and hence pyrolysis can be used in the treatment of the various plastic and biomass wastes. Charcoal was obtained in the case of teakwood shavings after pyrolysis. But the liquid distillate had excessive water content (60% by volume) that had to be removed by fractional distillation. Liquid fuel yield was more in case of polystyrene and the properties of the fuel were superior to other batches and comparable with diesel oil and suitable to be used in diesel engines. PET is not ideal for pyrolysis as the fuel properties are not satisfactory when compared with the rest. Although charred residue was formed in the chamber in every batch, none had the plastic properties. The fuel properties were observed to improve in case of co-pyrolysis of wood shavings and HDPE than biomass pyrolysis of wood alone.

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