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Production of Conventional Fuel from Plastic Waste and Biomass by Pyrolysis

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Abstract - The conversion of waste plastic into liquid fuel is an unintended outcome of the progress made toward more sustainable waste management.The best and optimum way to convert waste plastic is to do pyrolysis process by creating oxygen free atmosphere. This is an effective measure by converting waste plastic into combustible hydrocarbon liquid as an alternative fuel. The plastics used in this process include polypropylene, polyethylene and high-density polyethylene. In some trials, plastics were co-pyrolyzed with other materials such as biomass (rice husk). The fuel obtained was of high yield and could be brought in use for commercial purpose after creating a setup for large scale production. In our process we got nearly 65% yield of fuels. The quality of fuel after the process of pyrolysis of plastic and co-pyrolysis of plastic + biomass, is compared to conventional diesel fuel after purification to check the similarity between two. The fuel samples were analyzed through FTIR and the components present were identified. This oil, after purification, can be readily used in industries to heat the boilers. We believe that modifications in our process and use of biomass reduced the time required to carry out the process, increased the fuel yield. Residue was converted into Nano-silica by acid treatment which has a wide use as an adsorbent in industries. Thus,two problems such as waste plastic management and fuel shortage could be tackled simultaneously and hence through this method we could reduce thedamage caused to the environmental.

***Key Words*: Waste Plastic, Biomass, Pyrolysis, Co-pyrolysis, Characterization, Component Analysis, Fuel Oil, Petrol, Diesel**

1. INTRODUCTION

The paper involves in depth analysis and experimentation of plastics and biomass. To properly carry out the experiments and come to a concrete conclusion, the types and properties of the feed which is used need to be known and studied in brief.

1.1 What are plastics?

Plastics are an extensive variety of artificial or semi-artificial substances that use polymers as a chief ingredient. Like timber, paper or wool, plastics also are taken into consideration as natural substances. The plasticity of plasticsmakes it viable for them to be extruded, molded or pressed into solids of diverse shapes. An extensive variety of residences together with being lightweight, durable, bendy and less expensive to provide and the adaptability mentioned in advance has brought about its sizeable use.

1.2 Classification of Plastics

Plastics can be classified on the following basis:

- chemical structure of the polymer (as well as side chains)
- the chemical processes which are used to manufacture them
- their physical properties
- their reactions (and resistance) to various substances and processes
- qualities which are relevant to manufacturing / product design for a particular reason

1.2.1 Thermoplastics & Thermosetting Polymers One important classification of plastics is the degree to which the chemical processes can make them reversible ornot (physically and chemically).

Thermoplastics, when heated, do not undergo any chemical change in their composition. Thus, they can be molded repeatedly. Examples include polystyrene (PS), polyethylene (PE), polyvinyl chloride (PVC) and polypropylene (PP).

Thermosetting polymers (Thermosets) can melt and take shape only once. After they've solidified, they live stable. If reheated, thermosets decompose as opposed to soften. In this process, an irreversible chemical reaction occurs.

1.1.1 **1.2.2 Amorphous Plastics & Crystalline Plastics** Many plastics are absolutely amorphous (without a rather ordered molecular shape), inclusive of thermosets, polystyrene, and methyl methacrylate (PMMA). On the other hand, crystalline plastics exhibit a pattern in which the atoms are regularly spaced such as high-density polyethylene (HDPE), polybutylene terephthalate (PBT) and polyether ether ketone (PEEK).

1.2.3 Bio-degradable Plastics & Bio-plastics

Biodegradable plastics break down (degrade) upon exposure to sunlight, UV radiation, water, dampness, bacteria, enzymes or wind abrasion. Attack by insects, together with wax-worms and mealworms, also can be taken into consideration as kinds of biodegradation.

While most plastics are produced from petrochemicals, bio- plastics are made substantially from renewable plant materials like cellulose and starch. In order to finite limits of fossil gasoline reserves and to growing rangesof greenhouse gases caused in most cases through the burning of these fuels, the improvement of bio-plastics is a developing field.

1.3 Types of Plastics

- **Polyamides (PA) or (nylons):** fishing line, low-strength machine parts such as engine parts or gun frames, fibers, tubing & toothbrush bristles.
- **Polycarbonate (PC):** compact discs (CDs), eyeglasses, shields used in riots, security windows,traffic lights and lenses.
- **Polyester (PES):** fibers and textiles.
- **Polyethylene (PE):** a wide range of supermarket bags and plastic bottles.
- **High Density Polyethylene (HDPE):** detergent storage bottles, milk jugs and molded cases of plastic.
- **Low-Density Polyethylene (LDPE):** floor tiles, shower curtains, outdoor furniture as well as clamshell packaging.
- **Polyethylene Terephthalate (PET):** peanut butter jars, carbonated drink bottles, microwavable packaging and plastic film.
- **Polypropylene (PP):** bottle caps, drinking straws,yogurt containers, car fenders as well as bumpers and pressure pipe systems.
- **Polystyrene (PS):** foam peanuts, plastic food containers, plastic tableware, disposable plastic cups, food plates, cutlery, compact discs (CD) and boxes to store cassettes.
- **Polyvinyl Chloride (PVC):** plumbing pipes and gutters, insulation for electrical wires/cables, curtains, window frames and flooring.

1.4 Environmental Hazards due to Mismanagement of plastics

Plastics are non-biodegradable material. Time taken to biodegrade plastic is 300-500 years and therefore environmental hazards due to improper management includes following aspects:

1. Littered plastics spoils beauty of the city and choke drains and can cause serious problem to cattle if they consume it.

2. When garbage containing plastics is burnt, it maycause air pollution as it emits toxic gases.

3. Garbage mixed with plastics gives problem in landfill operation and pollutes the land.

1.5 Side effects of plastics in Nature

Durability and chemical structure of some organic compounds greatly influences their biodegradability. Therefore, an increased number of functional groups (groups of atoms) which are attached to the benzene molecule (in an organic molecule) usually hinder the attack of microorganisms. Instead of biodegradation, plastics waste is going via photo-degradation and becomes plastic dusts that can enter the living organisms and could cause serious health issues. Plastics are usually processed from derivatives of petroleum and are composed primarily of hydrocarbons but also contain antioxidants, colorants, and other stabilizers which are usually additives. However, these additives are undesirable from an environmental point of view when these plastic products are discarded. Burning of plastics give NOX, COX, SOX, particulate, dioxins and fumes to increaseair pollution which results in acid rain and increase in global warming. Plastics in land fill area results in leaching of toxins into ground water.

1.6 What is Biomass?

Biomass is obtained from natural substances, a renewable and sustainable supply of energy used to create electricity or different kinds of power. Green power manufacturing can hold indefinitely with a regular supply of waste – from creation and demolition activities, to timber now no longer utilized in papermaking, to municipal stable waste. Here is why Biomass is a renewable source of fuel to produce energy:

- Waste residues – in terms of scrap wood, mill residuals and forest resources - will always exist.
- Properly managed forests will always have more trees and crops and also the residual biological matter from those crops.

Biomass is considered a renewable energy source since organic matter can be replaced in a relatively short period of time. Burnt wood in a fireplace or a charcoal grill for cooking are examples of using biomass energy.

Before the mid-19th century, biomass used to be largest source of U.S. energy consumption. Biomass is still an important fuel for cooking and heating in other countries. Biomass is once again becoming an important energy source as countries see renewable energy as a way to avoid the carbon dioxide (CO2) emissions that come from burning fossil fuels.

1.7 Types of Biomass

1.7.1 Tree & Plant Waste

Any plant or wood waste can be burned to harness biomass energy whether it's produced by industrial manufacturing or by the average home. Some common waste from plants andtrees includes:

- Firewood, timber pellets and timber chips
- Sawdust
- Black liquor from pulp and paper mills
- Dead leaves and backyard clippings

1.7.2 Crops

Farm waste materials and agricultural crops can either be burned or allowed to decompose which will result in releaseof biomass energy. The most common crop waste comes from Corn, Soybeans, Sugarcane, Switch grass, Woody plants,Algae, Crop and foodprocessing residues.

1.7.3 Solid Waste

Any organic waste from human activity can be decomposed or burned to convert biomass energy into electricity. Solid waste can include Paper and paperboard, Textiles such as cotton and wool, Food waste, Rubber and leather.

1.7.4 Landfill Gas and Biogas

Organic waste is generated day by day from each land-fills and livestock farms which decomposes and in addition releases methane (CH4) this is ignited to release biomass energy. The biggest sources of methane are:

- Animal waste, accrued in massive tankspacked with micro-organism that consume the waste and convert it to methane.
- Landfill gas, largely methane, is collected by closing off a landfill and running pipes from the waste thatcollect the gas. If left to decompose on its own, these landfills and animal waste will release the methane gas into the open atmosphere. Methane is the second-biggest contributor to climate change when it's left to escape into the atmosphere as it is a potent greenhouse gas with 25 times the heat- trapping ability of carbon dioxide. So methanecould be captured to be used as a biomass energy supply and thus it will help reduce the effects of climate change in many ways.

2. MATERIALS & METHODOLOGY

2.1 Materials:

Waste Plastic (LDPE, HDPE & PP), rice husk, round bottom flask, electrical heater, nitrogen gas, condenser, thermometer, pipes, thermometer pocket, beaker, submersible pump, muffle furnace.

2.2 Methodology:

We chose thermal pyrolysis method for our experiment. It is an advanced conversion technology that has the ability to produce a clean, high calorific value hydrocarbon fromwaste (polyethylene). The detailed procedure is given below:

- Feed sample (waste plastic) was cleaned and shredded into small pieces and fed into the 1-liter round bottom flask.
- Nitrogen gas was purged into the round bottom flask through one of the inlets using a glass pipe connected via rubber pipe. From the other inlet, a thermometer pocket was inserted to measure the high temperatures inside.
- The third outlet of the round bottom flask was attached to a condenser, which had continuous water flow, collecting and condensing the vapors of melted plastic into a beaker put at the other end of the condenser.
- The heating was supplied through an electrical heater. The temperature when first drop of liquid came out was noted.
- The weight of the waxy residue was calculated at the end. The total time required for the experiment was also noted.
- Different properties of obtained liquid were tested.

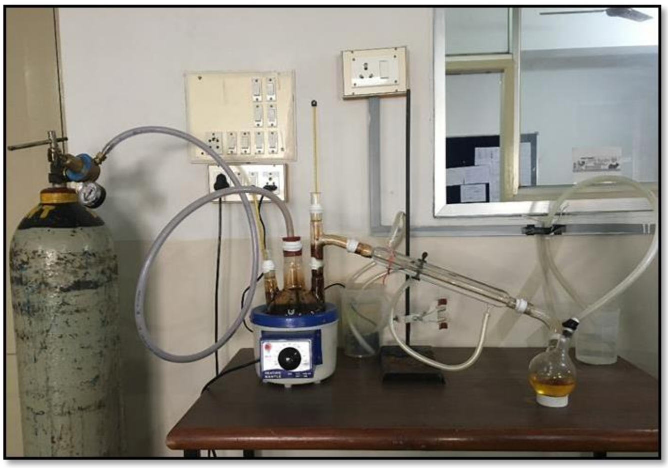

Fig. 1: Experimental Setup

Few trials were done by blending waste plastic and biomass (rice husk) which is called Co-pyrolysis method. The feed was taken in a ratio of 2:1 for plastic to biomass. The procedure is same as done for only plastic, as mentioned above. In some samples, especially the ones with biomass, little amounts of water was obtained along with the fuel oil.Hence to separate them re-distillation of the obtained fuel was also done.

The residue obtained from the co-pyrolysis method was used to synthesize Nano-Silica. The procedure is as follows:

- 10g Residue (rice husk) was treatedwith 30 ml, 1N HCl and kept in oven at 80^{o}C for 2 hours and left overnight.
- It is then filtered the next day with distilled water.
- At this step, Silica is obtained which is dried at110^{o}C and then kept in muffle furnace at 700^{o}Cfor 2 hours.

Finally, Nano-Silica, a white powdered substance is obtained.

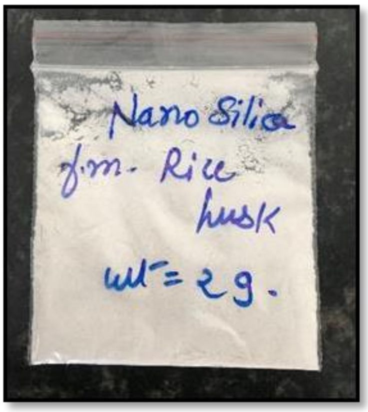

Fig. 2: Nano Silica (2 g)

Fig. 3: 10 ml samples of fuels obtained.

(From L to R: LDPE, LDPE+biomass, LDPE+Biomass+Saw Dust, PP, PP+Biomass, HDPE, HDPE+Biomass)

Fig. 4: Re-Distillation of Fuel Samples

3. OBSERVATIONS & RESULTS

After successful completion of all the batches of plastics and biomass, the following observations were made and results were obtained.

Table 1: Observations of all the 8 batches

BATCH No.	Plastic type	Feed (g)	Output (weight %)			Temperature (º C)	Percentage Yield (%)
			Liquid	Gas	Residue		
BATCH 1	LDPE(Plastic Bag)	250	59	18.4	22.4	276	59
BATCH 2	LDPE(Plastic Bag)	300	69.6	13.3	17	298	69.6
BATCH 3	HDPE	150	16.6	14.6	68.7	250.6	16.6
BATCH 4	PP	150	55	21.3	23.3	237.8	55
BATCH 5	LDPE + Milk Bag + Sawdust + Rice Husk	250	64	28	8	97	64
BATCH 6	LDPE + Rice Husk	150	34.5	15.4	50	203.4	34.5
BATCH 7	HDPE + Rice Husk	150	43	14	42.6	168.6	43
BATCH 8	PP + Rice Husk	150	52.6	19.2	28.1	186.6	52.67

Table 2: Properties compared with Gasoline/Diesel

Physical Properties	Type of Plastics							Commercial Standard Value (ASTM 1979)	
	LDPE (Plastic Bag)	LDPE (Plastic Bag)	HDPE	PP	LDPE + Milk Bag + Saw dust + Rice Husk	LDPE + Rice Husk	HDPE + Rice Husk	PP + Rice Husk	Gasoline	Diesel
Density (g/c^3)	0.819	0.819	0.691	0.691	0.707	0.761	0.845	0.759	0.780	0.807
Viscosity (cP)	2.3	2.3	0.537	0.724	0.921	0.720	0.702	0.675	0.91	1.5-3
Calorific value (MJ/kg)	39.1	39.1	45.4	40	37	38.4	40.1	40	42.5	43.0
Flash point(°C)	80.4	80.4	44	33	113.1	100	63.6	54.2	42	52
Fire Point(°C)	85.5	85.5	50	39	119	105	68.7	59.4	49	93.3

Pour point (^{0}C)	<-10	<-10	<-10	<-10	<-10	<-10	<-10	<-10	-	-30
Cloud Point (^{o}C)	-8	-8	<-5	<-5	<-5	<-5	<-5	<-5	-18	-6

4. ANALYSIS

The fuel samples were then analyzed through FTIR foridentification of further components in the fuel. Here are theresults of the analysis done.

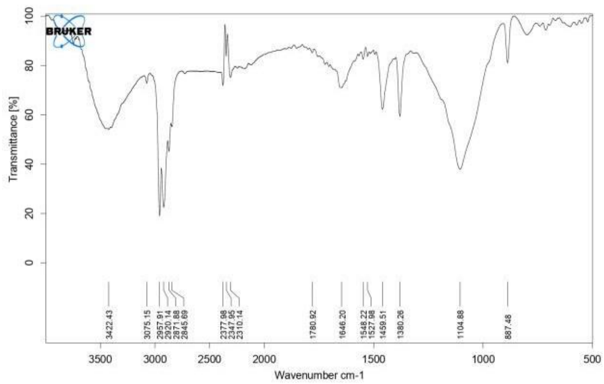

Fig. 5: Analysis of Fuel oil from LDPE

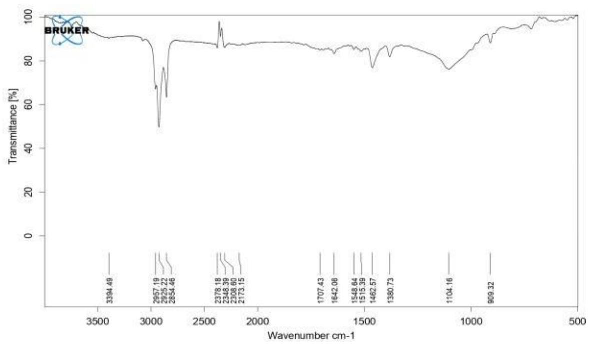

Fig. 8: Analysis of Fuel oil from LDPE + Biomass

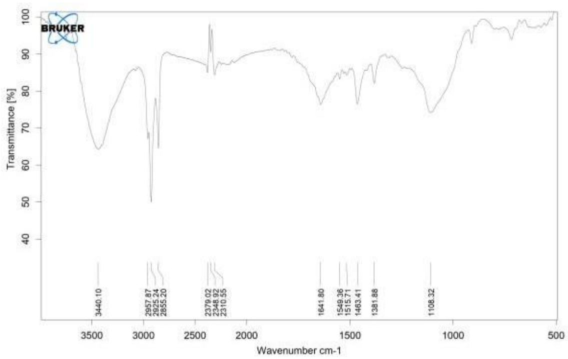

Fig. 6: Analysis of Fuel oil from HDPE

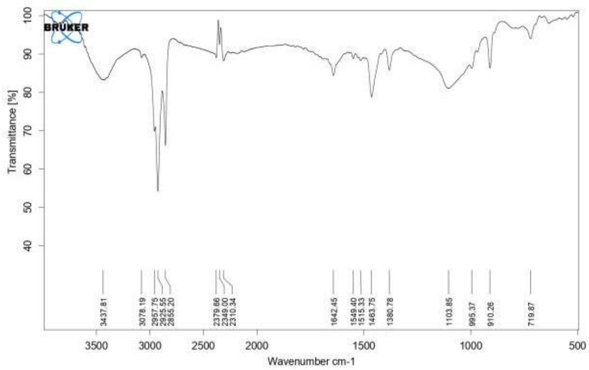

Fig. 9: Analysis of Fuel oil from HDPE + Biomass

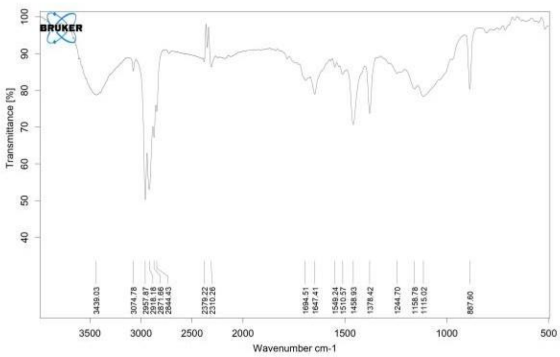

Fig. 7: Analysis of Fuel oil from PP

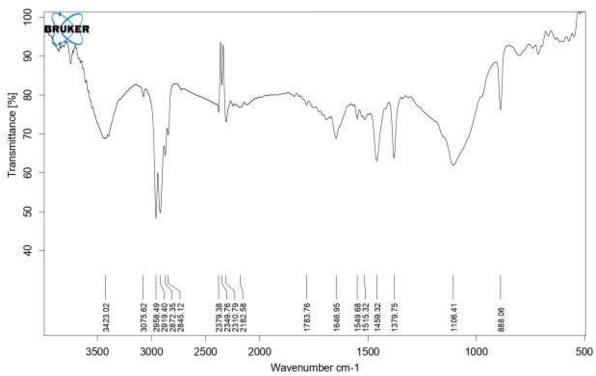

Fig. 10: Analysis of Fuel oil from PP + Biomass

5. CONCLUSIONS

From the analysis and observations shown above, wecan see that the percentage yield of fuel oil obtained from pyrolysis of LDPE has increased from 59% to 64% after addition of saw dust and rice husk to the feed. And the amount of fuel oil obtained from pyrolysis of HDPE infused with Rice Husk increased by almost 260% compared to pyrolysis of HDPE alone - which means pyrolysis of only HDPE produced about 16.6% liquid fuel whereas pyrolysis of HDPE and Rice Huskproduced 43% liquid fuel. Both these inferences show us that addition of biomass increases the yield of liquid oil obtained. This in turn reduces the amount of residue obtained too. The amount of gases obtained remains the same for HDPE. On the other hand, flash point and fire point of fuel oil obtained from pyrolysis of plastics infused with biomass is more than that of fuel oil obtained from pyrolysis of plastics alone. These high temperatures make it easier to store the fuels in surroundings with lower temperatures which in turn reduce the possibility of fire hazards taking place. The possible reasons for improvement can be the synergistic effects of biomass and plastic. Here biomass performs as an auto-catalyst in the reactions. Moreover, the fuel oil obtained from pyrolysis of LDPE turns out to be similar to diesel with most of its parameters aligning closetothose of diesel.

As discussed beforehand, we face issues regarding shortage of fossil fuels and improper management of solid waste generated globally. Co-pyrolysis has been proved to give better quality fuels with increased quantity too. And in addition to this, the analysis of the co-pyrolysis technology above does not involve the use of catalysts, hydrogen pressure or any kinds of solvents. The synergistic effects between various types of biomass and plastics have proved to be an area of interest where very less research is done. Using biomass into this process proves economical and effective in terms of biomass waste management. Moreover, generation of plastic waste at an enormous rateannually and globally plays a major role in substituting the issue of depletion of fossil fuels, as plastics are additive materials for co-pyrolysis. Considering the rapid growth of countries worldwide, economically and population-wise, more and more waste will be generated which will increase the need ofwaste management. In further addition to the benefits of using co-pyrolysis technology, it helps in stabilizing the economy as the costs to treat solid waste separately reducesand a useful product Nano-Silica is obtained and environmental issues which follow is also reduced. From the discussion above, we come to a conclusion that Co-pyrolysis proves to be a trust-worthy technology for tackling two major issues – solid waste management and over dependency on fossil fuels.

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