

## Alternate Fuel from Synthetic Plastics Waste - Review

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### ABSTRACT

Waste plastics are one of the most promising resources for fuel production because of its high heat of combustion and due to the increasing availability in local communities. Unlike paper and wood, plastics do not absorb much moisture and the water content of plastics is far lower than the water content of biomass such as crops and kitchen wastes. The conversion methods of waste plastics into fuel depend on the types of plastics to be targeted and the properties of other wastes that might be used in the process. Additionally the effective conversion requires appropriate technologies to be selected according to local economic, environmental, social and technical characteristics. In general, the conversion of waste plastic into fuel requires feedstocks which are non-hazardous and combustible. In particular each type of waste plastic conversion method has its own suitable feedstock. The composition of the plastics used as feedstock may be very different and some plastic articles might contain undesirable substances (e.g. additives such as flame-retardants containing bromine and antimony compounds or plastics containing nitrogen, halogens, sulfur or any other hazardous substances) which pose potential risks to humans and to the environment.

Pyrolysis is the thermal disintegration of carbonaceous material in oxygen-starved atmosphere. When optimized, the most likely compounds formed are methane, carbon monoxide, hydrogen carbon dioxide and water molecules. The yields of different products depend very much on the process variables. The pyrolytic oil can be blended with the conventional liquid fuels. The pyrolytic waste disposal will also mitigate the problems of environmental pollution.

**Keywords:** Plastics waste, Pyrolysis, Alternate fuel.

### INTRODUCTION

As a brief introduction to plastics, it can be said that plastics are synthetic organic materials produced by polymerization. They are typically of high molecular mass, and may contain other substances besides polymers to improve performance and/or reduce costs. These polymers can be moulded or extruded into desired shapes. There are two main types of plastics: thermoplastics and thermosetting polymers.

1. **Thermoplastics** can repeatedly soften and melt if enough heat is applied and hardened on cooling, so that they can be made into new plastics products. Examples are polyethylene, polystyrene and polyvinyl chloride, among others.

2. **Thermosets** or **thermosettings** can melt and take shape only once. They are not suitable for repeated heat treatments; therefore after they have solidified, they stay solid.

Examples are phenol formaldehyde and urea formaldehyde. Waste plastics their disposal creates large problems for the environment. Waste plastics do not biodegrade in landfills, are not easily recycled, and degrade in quality during the recycling process. Instead of biodegradation, plastics waste goes through photo-degradation and turns into plastic dusts which can enter in the food chain and can cause complex health issues to earth habitants. According to a nationwide survey, conducted in the year 2003, more than 15342.46 T of plastic waste is generated daily in our country, and only 40% wt of the same is recycled, balance 60% wt is not possible to dispose off. It is projected that annual post-consumer plastic waste has been reached 5.6 million tons by the year 2008-2009. At these alarming levels of waste plastics generation, India needs to prepare a lot in recycling and disposing the waste. Several processes and means have been attempted to fight against these alarming levels of waste plastics generation. However each process had its

drawbacks and economical operational & financial limitations for practical implementation. In this contrast, chemical process such as pyrolysis can be used to safely convert waste plastics into hydrocarbon fuels that can be used for transportation.

Pyrolysis is a state of the art technology, which integrates the thermo-chemical properties of plasma with the pyrolysis process. The intense and versatile heat generation capabilities of Pyrolysis technology enable it to dispose of all types of plastic waste including polymeric, biomedical and hazardous waste in a safe and reliable manner. Pyrolysis is the thermal disintegration of carbonaceous material in oxygen-starved atmosphere. When optimized, the most likely compounds formed are methane, carbon monoxide, hydrogen carbon dioxide and water molecules.

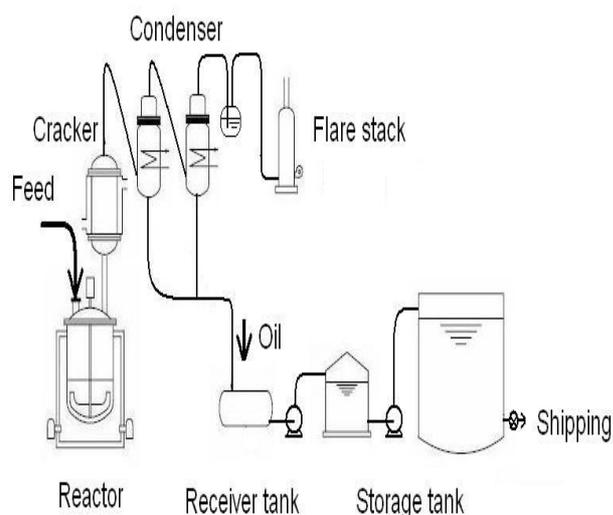
All plastics are polymers mostly containing carbon and hydrogen and few other elements like chlorine, nitrogen etc. polymers are made up of small molecules called as monomers which combine and form single large molecule called polymer. When this long chain of monomers breaks at certain points or when lower molecular weight fractions are formed this is termed as degradation of polymer. This is reverse of polymerization. If such scission of bonds occurs randomly it is called as 'Random De-Polymerization'. In the process of conversion of waste plastic into fuels random De-Polymerization is carried out in a specially designed Reactor in absence of oxygen & in the presence of coal and certain catalytic additive. The maximum reaction temperature is 550°C. There is Total conversion of waste plastic into value added fuel products.

Liquid fuel is defined as plastic-derived liquid hydrocarbons at a normal temperature and pressure. Only several types of thermoplastics undergo thermal decomposition to yield liquid hydrocarbons used as liquid fuel. PE, PP, and PS, are preferred for the feedstock of the production of liquid hydrocarbons. The addition of thermosetting plastics, wood, and paper to feedstock leads to the formation of carbonous substance. It lowers the rate and yields of liquid products. Depending on the components of the waste plastic being used as feedstock for fuel production, the resulting liquid fuel may contain other contaminants such as amines, alcohols, waxy hydrocarbons and some inorganic substances. Contamination of nitrogen, sulfur and halogens gives flu gas pollution. Unexpected contamination and high water contents may lower the product yields and shorten the lifetime of a reactor for pyrolysis Liquid fuel users require petroleum

substitutes such as gasoline, diesel fuel and heavy oil. In these fuels, various additives are often mixed with the liquid hydrocarbons to improve the burner or the engine performance. The fuel properties such as viscosity and ash content should conform to the specifications of the fuel user's burners or engines. No additives would be needed for fuel used in a boiler. A JIS technical specification was proposed for pyrolytic oil generated from waste plastic for use as boiler and diesel generator fuel (TS Z 0025:2004). Skillful operators and a well-equipped facility are required due to the formation of highly flammable liquids and gases.

#### MATERIALS AND METHOD

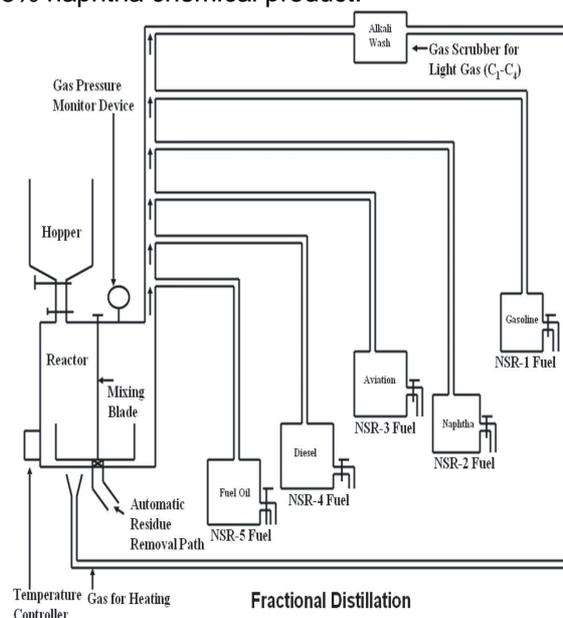
The production method for the conversion of plastics to liquid fuel is based on the pyrolysis of the plastics and the condensation of the resulting hydrocarbons. Pyrolysis refers to the thermal decomposition of the matter under an inert gas like nitrogen. For the production process of liquid fuel, the plastics that are suitable for the conversion are introduced into a reactor where they will decompose at 450 to 550 °C. Depending on the pyrolysis conditions and the type of plastic used, carbonous matter gradually develops as a deposit on the inner surface of the reactor. After pyrolysis, this deposit should be removed from the reactor in order to maintain the heat conduction efficiency of the reactor. The resulting oil (mixture of liquid hydrocarbons) is continuously distilled once the waste plastics inside the reactor are decomposed enough to evaporate upon reaching the reaction temperature. The evaporated oil is further cracked with a catalyst. The boiling point of the produced oil is controlled by the operation conditions of the reactor, the cracker and the condenser. In some cases, distillation equipment is installed to perform fractional distillation to meet the user's requirements. After the resulting hydrocarbons are distilled from the reactor, some hydrocarbons with high boiling points such as diesel, kerosene and gasoline are condensed in a water-cooled condenser. The liquid hydrocarbons are then collected in a storage tank through a receiver tank. Gaseous hydrocarbons such as methane, ethane, propylene and butanes cannot be condensed and are therefore incinerated in a flare stack. This flare stack is required when the volume of the exhaust gas emitted from the reactor is expected to be large.



**Fig. 1: presents a schematic diagram of a liquid fuel production plant**

A small-scale conversion process has been performed with the simplified process shown in Figure 2 using various types of mixed waste plastics: high-density polyethylene (HDPE-2), low-density polyethylene (LDPE-4), polypropylene (PP-5) and polystyrene (PS-6). The plastics are collected, optionally sorted and cleaned of contaminants. These plastic types were investigated singly and in combination with other plastic types. The plastics were grinded into small pieces in sizes of 14–15 mm. These small plastic pieces were analyzed by EA-2400 (elemental analyzer) in CHNS mode to find the compositions. The analysis is presented as 86% being C, 12% being H, 0.9% being N and about 1.1% being S. The process of conversion involves heating of the waste plastic to form liquid slurry, thermal liquefaction of 370–420 °C of the slurry, distilling the slurry in the presence of cracking with catalyst and also without catalyst, condensing the liquid slurry with distillate to recover the liquid hydrocarbon liquid fuel materials, no additional chemicals are used in the thermal degradation process. In the mini-scale conversion process, the weight of a single batch of input plastics for the fuel production process ranges from 300 gm to 3 kg. Produced fuel is called 1st (gasoline), 2nd

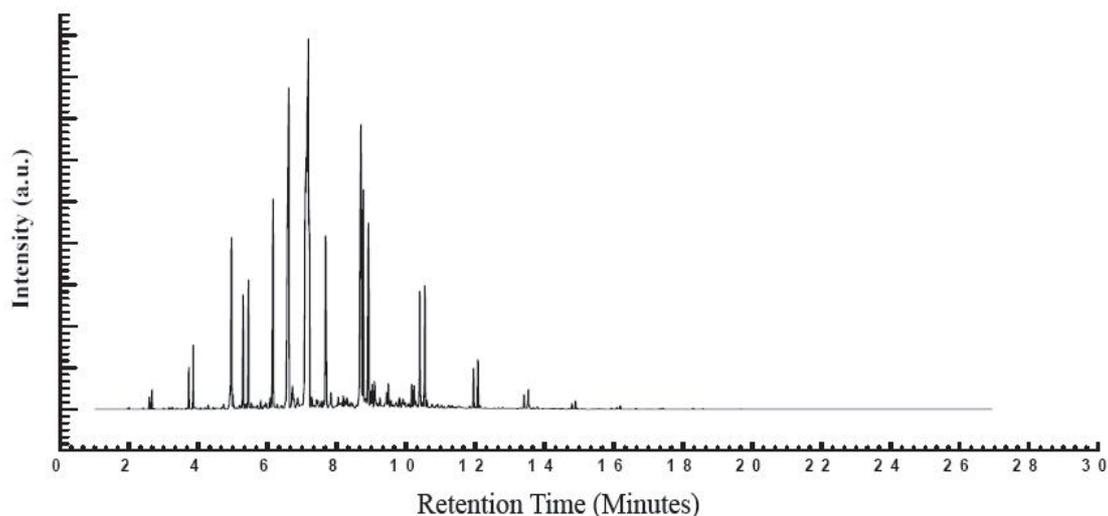
(naphtha), 3rd (aviation), 4th (diesel) and 5th (fuel oil) fraction fuel. Also, during the production process, light gases ranging from C1 to C4 are produced and about 3% residue is leftover from the production process. The residue is black colored and contains high BTU value. The 2nd fraction distillation fuel (Figure 1) is called naphtha chemical. The 2nd fraction distillation tower temperature is used at 110–150 °C. Further, fractional distillation NSR fuel production technology obtains almost 38% naphtha chemical product.



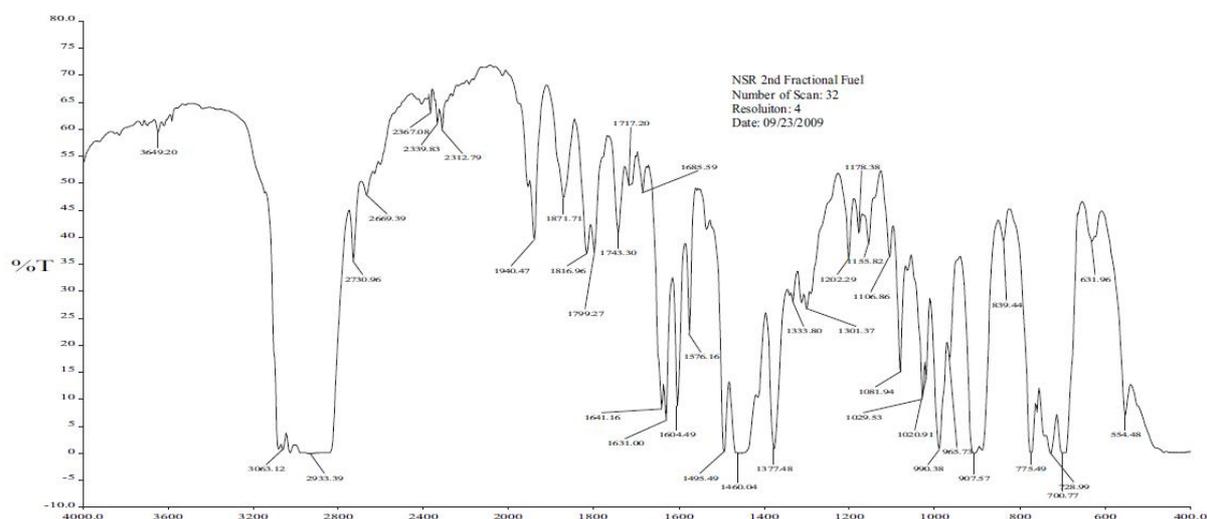
**Fig 2: waste plastics to fuel**

## RESULTS AND DISCUSSION

GC/MS tests have been performed to investigate the composition of the produced 2<sup>nd</sup> fraction fuel. The GC/MS Clarus 500 instrument is a product of Perkin Elmer and it uses the Turbo mass software to operate all its functions. An Elite-5ms 30 m, 0.25mm ID column was used. The temperature conditions are from 35 °C to 250 °C. The ramping rate of 4 °C/min to 130 °C holds for 1 min and ramp 2 of 10 °C/min to 250 °C holds for 5 min. Helium is used as a carrier gas. Figure 3 shows chromatograms of producing 2<sup>nd</sup> fraction fuel illustrating the carbon chain length.



**Fig 3: Gas chromatography and mass spectrometer chromatogram of waste plastic to produce naphtha category Chemical**



**Fig 4: FTIR spectrum of waste plastic to produce naphtha chemical**

The 2<sup>nd</sup> fraction carbon chain is C<sub>6</sub>–C<sub>14</sub>. Gas chromatography and mass spectrometer (GC/MS) show higher peak intensity with retention-time major compound distribution throughout the range of hydrocarbon groups C<sub>6</sub>–C<sub>14</sub>, with retention time ranging from 2 min to 27 min. From FTIR (Spectrum 100) analysis of NSR 2<sup>nd</sup> fractional fuel, we found a perceptible spectrum that has different peak points that we consider as wave numbers. According to the wave numbers in NSR 2<sup>nd</sup> fractional fuel, functional groups are (Figure) = –C–H, C–CH<sub>3</sub>, non-conjugated, conjugated, CH<sub>2</sub>, CH<sub>3</sub>, acetates, secondary cyclic alcohol, –CH=CH<sub>2</sub> and –CH=CH–(cis). It appears that some functional groups reiterate because their

wave number is repeated, such as C–CH<sub>3</sub>, non-conjugated, conjugated, acetates and –CH=CH–(cis) groups. Besides, against some wave numbers, we did not find any functional groups but that numbers are not as much as in quantity. It is evident that FTIR analysis of NSR 2<sup>nd</sup> fractional fuel contains maximum numbers of functional groups (hydrocarbon compounds). Results obtained from Elemental Analyzer (EA) – 2400 indicates that NSR fuel contains 85.44% carbon and 12.96% hydrogen. The average of the fractionated fuels contains 85.00% carbon and 13.00% hydrogen. The empirical formula indicates that the Naphtha Chemical product's carbon and hydrogen ratio is 1:2 and the carbon hydrogen ratio is 6.53.

## CONCLUSION

It is very much essential to scientifically dispose the ever increasing solid wastes generated by the growing population. Pyrolysis of solid wastes is one of the safe methods of disposal. The pyrolysis of scrap has produced solid char containing steel wires which can be recycled and the percentage of liquid oil collected is more than that of gases. The temperature rise of the pyrolyser is faster due to better heat transfer inside the reactor. The pyrolysis of LDPE has produced only a little char, but the percentage of volatiles is high which can be largely converted to liquid oil, theoretically up to 100 %. The temperature rise is slower when compared to that of scrap tyres and PVC due to poor heat transfer characteristics and drastic physical changes taking place during pyrolysis. The pyrolysis of PVC has produced more solid char than LDPE, but the evolution of HCl vapours requires pretreatment as they are strongly acidic. The temperature rise of the pyrolyser is faster than that for LDPE. The average specific reactivity of screened MSW is very low when compared to that of scrap tyres, LDPE, PVC and dry leaves due to the presence of inert materials in it. The specific electrical energy consumption during pyrolysis is lowest for scrap tyre, and highest for PVC. The pyrolysis of PVC can be safely done only with the integration of a downstream treatment process for HCl vapours. A real pyrolyser plant can be operated by deriving heat from a portion of the feed stock itself, instead of the electrical heating practiced in the case of lab scale pyrolyser.

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