



HIGH ENERGY CONTENT LIQUID HYDROCARBON FUEL FROM MIXTURE OF POLYPROPYLENE AND POLYSTYRENE WASTE PLASTICS USING THERMAL CRACKING AND ACTIVATED CARBON

Moinuddin Sarker* and Mohammad Mamunor Rashid

Department of Research and Development, Natural State Research Inc, 37 Brown House Road (2nd Floor)
Stamford, CT- 06902, USA, Phone: (203)406 0675, Fax: (203) 406 9852

*Corresponding Author: Dr. Moinuddin Sarker, VP of R & D, Head of Science Team, Natural State Research, Inc., e-mail: msarker@naturalstateresearch.com
37 Brown House Road (2nd Floor), Stamford, CT-06902, USA

Received for publication: November 08, 2012; Accepted: December 28, 2012.

Abstract: In this current society, petroleum is a big factor to meet the world's energy demand. According to statistics, the consumption of petroleum is much higher than its production rate. Furthermore, countries around the world spend large amounts of money each year to import fossil fuel, which can cause major deflation in a countries economy. Many alternative proposals have been made to overcome the petroleum issue. Alternate energy sources have been developed based on reliable sources to reduce the demand of petroleum, but these sources require vast amount of land and financial complication. Research based on conversion of waste plastic into high energy content liquid fuel has the potential to overcome the world's energy demand. Unlike fossil fuel, the source of waste plastic is virtually unlimited. Nearly 48 million tons of waste plastic is generated in the US alone. From this amount 65% is landfill, 25% is incineration and 10% is for recycling purpose. Waste plastic is not biodegradable it can remain for a long period in land fill. Incineration and recycle process crating toxic gas and affecting greenhouse gas. The presence of these waste plastic on landfill causes variety of environmental and health problems. Natural State Research Inc has developed unique technology that will remove these waste plastics from landfill and convert them into high energy content liquid hydrocarbon fuel. Preliminary test have shown that waste plastic converted into fuel burns cleaner than the current commercial fuels and it can be produced a lower cost due to its primary source being waste plastic. The present technology has already shown the capability to produce this fuel from waste plastics in a laboratory scale and plans to move on into pilot and commercialization plant.

Keywords: Energy, Hydrocarbon Fuel, Waste Plastic, Thermal Cracking, Activated Carbon, Polypropylene, Polystyrene

INTRODUCTION

The disposal of waste plastics generated in the U.S. is posing a serious environmental problem. In recent years, liquefaction of waste plastics and their co-liquefaction with coal is being investigated as an alternative to landfill disposal. Conversion of waste plastics to liquid fuels is logical, since plastics are very rich in hydrogen and carbon; the atomic H/C ratio, vis-a-vis coal, is closer to that in petroleum [1]. Approximately 15 million tons of postconsumer plastic wastes are generated throughout Europe each year, while in the United States 20 million tons of waste is generated. The waste arises from a number of sources including agriculture, automotive, construction, distribution and domestic use. Most of the postconsumer plastic is land filled or incinerated, and on average, only 7% is recycled to produce low-grade plastic products such as plastic sacks, pipes, plastic fencing, and garden furniture. The low-grade used for mixed plastic recycled materials has led to research into alternative processing methods to produce higher value products. There are six main plastics which arise

in municipal solid waste, high-density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), poly(vinyl chloride) (PVC), and poly- (ethylene terephthalate) (PET) [2,3]. Post-consumer wastes have caused increased concern because of the escalation of municipal solid wastes (MSWs) generated. Plastics make up a significant portion of MSWs. In the United States alone, over 21.5 million tons of plastics are manufactured annually, and production is projected to increase to 26.7 million tons in 2005. In 1997 9.9wt % of MSWs comprised of plastics, which was more than 20vol % increase from previous years. Within the plastic waste stream, 13.0wt% was composed of polypropylene (PP) and 9.8wt % contained polystyrene (PS) [4]. Concern about environmental preservation and current legislation in this field are the causes of the increase in waste plastic recycling. Domestic plastic wastes contain 57wt % polyolefin' s, 14wt % poly (vinyl chloride), 19wt % polystyrene, 5wt % other plastics and paper and 5wt % inorganic materials (additives). The



European Union and Japan are currently leaders in plastic recycling, although the annual rate of increase in the U.S. is 12%. In Germany, 64wt % packing material is recycled and incineration is forbidden throughout the country. In Italy, 40wt % plastic packages are recycled, and Japan has set a 50wt % goal for the year 2000. Although combustion is an alternative to disposal in rubbish dumps (where harmful methane is produced), it must be subjected to severe environmental controls in order to meet the legal restrictions concerning the emission of solid particles and gaseous effluents. This strategy is being abandoned in spite of the high calorific value of the plastics (polyethylene, 43 MJ/kg; polypropylene, 44 MJ/kg; poly (vinyl chloride), 20 MJ/kg).

In Europe, secondary recycling (by grinding, re-melting, and reshaping into lower-value products, such as fillers and fibers) is limited to 20wt % plastic wastes. Most of the present research effort is centered on tertiary recycling, with the aim of incorporating the recycling technology into the routine operation of the petrochemical industry. By means of solvolysis (methanolysis, glycolysis, hydrolysis, aminolysis, etc.), condensation polymers such as poly(ethylene terephthalate) and urethane can be decomposed into raw materials, while addition polymers, such as polyolefin's, polystyrene, and poly(vinyl chloride), require thermal treatment (pyrolysis, thermal cracking), gasification, or catalytic degradation. These thermal-catalytic treatments are very versatile and more easily performed when carried out in a refinery [5]. The consumption of plastics in Europe in 1998 was about 30.4 million tones. The main components of this were linear low and low-density polyethylene (L/LDPE 23%), high-density polyethylene (HDPE 15%), and polypropylene (PP 20%). Around 58% of this consumption became waste, resulting in nearly 17.6 million tons of plastic disposal over the same period. Almost 60% of the total production was destined for the household market, mainly for use in packaging, and nearly 70% of these plastics ended up in the municipal solid waste (MSW). Because of increasing political concern in the governments and society as a whole toward environmental issues, a great deal of research has been done over the last 2 decades into recycling methods to deal with this amount of waste in an economic and ecological way. Numerous processes have been developed from this research, some of them focused on the recovery of energy from the plastics incineration and others focused on the combined

recovery of the energetic and chemical value of the plastic.

Thermolysis, pyrolysis or gasification are the names associated with this latter kind of process and in this report they will be referred to as feedstock recycling or pyrolytic processes [6]. Some research group also investigation waste plastic to fuel production process by using pyrolysis process [7-8], thermal process [9-10] and catalytic cracking process [11-12]. Natural state research Inc., implement a unique thermal process to converting municipal solid waste plastic into liquid hydrocarbon fuel by using thermal degradation process without any catalysts. The fuel production yield percentage is much higher 95% as well as derived solid black residue and light gases such as methane, ethane, propane and butane and some alkenes group present.

EXPERIMENTAL SECTION

Raw Sample Pre-Analysis:

The waste plastic PP (Code-5) and PS (Code-6) plastic sample was used in this experiment and waste plastics obtained from local city supermarkets and groceries. The waste PP and PS waste plastics sample was sorted and cleaned off contamination using detergent and water. The washed waste plastics sample was dried with air dry. Then the dried sample was cut and grinded before putting it inside the steel reactor. The grinded PP and PS samples grinded size ranges from (2-3) mm. The sample was pre-analyzed using Gas Chromatography and Mass Spectrometer (GC/MS) Model No. Clarus 500 with CDS pyroprobe, FT-IR Spectrum 100, and Thermogravimetric (TGA Pyris-1) analyzer.

For raw materials PP and PS waste plastic analysis purposed GC/MS with CDS pyroprobe was use and chromatogram shown figure1 and Figure.2. GC program was setup initial temperature 40°C and hold for 2 minutes, maximum temperature was 350°C, ramping rate 6°C/minute to 295°C and hold for 5 minutes. Total run time was 49.50 minutes. Carrier gas was used Helium. MS method was setup for analysis purposed MS scan time 1-49.50 minutes and Mass 35.00-350.00 EI+. Capillary column was used for raw sample analysis purposed column length was 30 meters ID 0.25, DF 0.5 and column temperature range was -60- 350°C. For GC/MS analysis purposed NIST library was use and solid raw sample volatile purpose temperature range was 1000 -1200°C.

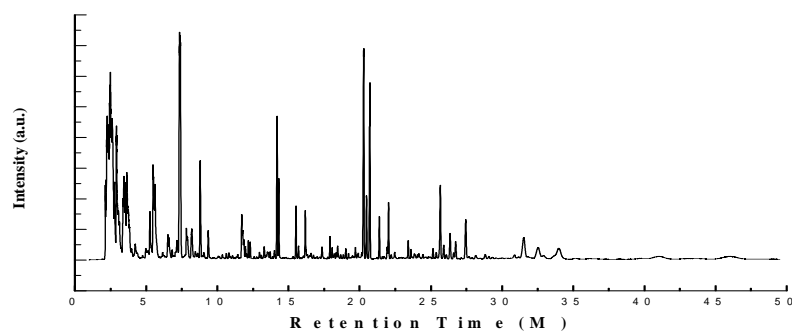


Figure.1: GC/MS Chromatogram of Polypropylene (PP) Raw Waste Plastic

Table: GC/MS Chromatogram Compound list of PP Raw Waste Plastic

Retention Time (M)	Compound Name	Compound Formula	Retention Time (M)	Compound Name	Compound Formula
2.13	Cyclopropane	C ₃ H ₆	12.29	Decane, 4-methyl-	C ₁₁ H ₂₄
2.26	1-Butyne	C ₄ H ₆	14.18	2-Dodecene, (E)-	C ₁₂ H ₂₄
2.45	2-Buten-1-ol, (E)-	C ₄ H ₈ O	14.30	1-Tetradecene	C ₁₄ H ₂₈
2.60	Cyclopropane, 1,2-dimethyl-, trans-	C ₅ H ₁₀	15.52	1-Dodecanol, 3,7,11-trimethyl-	C ₁₅ H ₃₂ O
2.76	3-Penten-2-ol	C ₅ H ₁₀ O	16.17	(2,4,6-Trimethylcyclohexyl) methanol	C ₁₀ H ₂₀ O
2.90	1-Pentene, 3-methyl-	C ₆ H ₁₂	17.35	Naphthalene	C ₁₀ H ₈
3.44	2,4-Hexadien-1-ol	C ₆ H ₁₀ O	17.90	3-Tetradecene, (E)-	C ₁₄ H ₂₈
3.54	2,4-Dimethyl 1,4-pentadiene	C ₇ H ₁₂	18.06	5-Tetradecene, (Z)-	C ₁₄ H ₂₈
5.27	2-Hexene, 3,5-dimethyl-	C ₈ H ₁₆	18.45	2-Hexyl-1-octanol	C ₁₄ H ₃₀ O
5.49	1,3,5-Cycloheptatriene	C ₇ H ₈	19.21	Isotridecanol-	C ₁₃ H ₂₈ O
5.62	trans-3,5-Dimethylcyclohexene	C ₈ H ₁₄	19.69	(2,4,6-Trimethylcyclohexyl) methanol	C ₁₀ H ₂₀ O
6.52	3-Heptene, 2,6-dimethyl-	C ₉ H ₁₈	20.72	1-Decanol, 2-hexyl-	C ₁₆ H ₃₄ O
6.59	2,3-Dimethyl-3-heptene, (Z)-	C ₉ H ₁₈	21.37	9-Eicosene, (E)-	C ₂₀ H ₄₀
7.35	Ethanone, 1-cyclohexyl-	C ₈ H ₁₄ O	21.93	1-Decanol, 2-hexyl-	C ₁₆ H ₃₄ O
7.38	4,4-Dimethyl-cyclohex-2-en-1-ol	C ₈ H ₁₄ O	22.03	Cyclododecanemethanol	C ₁₃ H ₂₆ O
7.41	2-Heptenal, 2-methyl-	C ₈ H ₁₄ O	22.45	11-Dodecen-1-ol difluoroacetate	C ₁₄ H ₂₄ F ₂ O ₂
7.82	Cyclohexane, 1,3,5-trimethyl-	C ₉ H ₁₈	23.40	3-Heptadecene, (Z)-	C ₁₇ H ₃₄
8.20	p-Xylene	C ₈ H ₁₀	25.14	Cyclododecanemethanol	C ₁₃ H ₂₆ O
8.78	3-Octene, 2,2-dimethyl-	C ₁₀ H ₂₀	25.67	1-Octadecene	C ₁₈ H ₃₆
9.36	1,6-Octadiene, 2,5-dimethyl-, (E)-	C ₁₀ H ₁₈	26.35	1-Hexadecanol, 3,7,11,15-tetramethyl-	C ₂₀ H ₄₂ O
11.71	Nonane, 2-methyl-3 methylene-	C ₁₁ H ₂₂	31.52	1-Heneicosyl formate	C ₂₂ H ₄₄ O ₂
11.78	1-Ethyl-2,2,6-trimethylcyclohexane	C ₁₁ H ₂₂	32.51	1-Nonadecanol	C ₁₉ H ₄₀ O
12.17	Nonane, 2,6-dimethyl-	C ₁₁ H ₂₄	33.98	1,22-Docosanediol	C ₂₂ H ₄₆ O ₂

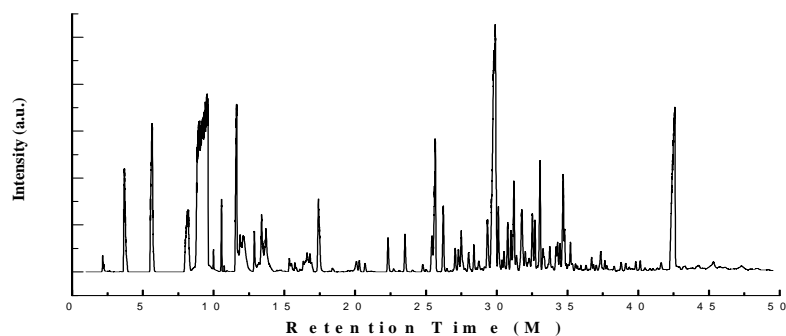


Figure.2: GC/MS Chromatogram of Polystyrene (PS) Raw Waste Plastic

Initial raw materials polypropylene (PP) waste plastic was analysis by GC/MS with CDS pyroprobe, and chromatogram and detected compounds showed Figure.1 and table.1. The GC/MS analysis result shows that the raw sample contained mostly double bond compounds are present in the raw PP plastic. From GC/MS analysis the raw PP waste plastic hydrocarbon compound ranges from C₃ – C₂₂ with different retention times. Compounds was detected based on compounds traced mass (m/z) and retention time (m). Analysis compounds table showed also oxygen contain compounds and alcoholic compounds are available in this raw material.

Initial raw material polystyrene (PS) waste plastic was analysis by GC/MS and chromatogram and compounds table showed Figure.2 and table.2. In analysis table showed that the raw sample contained mostly double bond and mostly aromatics compounds are present in the raw PS plastic. From GC/MS analysis result showed raw PS plastic compound ranges from C₃-C₂₈ with different retention times. All compounds was detected based on compound retention time (m) and compound trace mass (m/z). Polystyrene waste

plastic has aromatic compounds and compounds table showed most of the aromatic compounds with hydrocarbon content.

Process Description:

The process involves heating the waste plastic to form liquid slurry and thermal liquefaction in the range was 25 - 450°C, distilling the slurry without the presence of catalyst, the slurry then converts in to gaseous vapor and the vapor is condensed through a standard condenser to obtain the final liquid hydrocarbon fuel product its call plastic fuel. Also as a byproduct light flammable gasses (Methane, Ethane, Propane and Butane) are obtained during both thermal degradation processes. The light gas is cleaned using alkali wash. At the end of the production a solid coke like solid hard residue remains in the reactor bottom, and this residue can be used for roofing and road carpeting. This process was carried out under normal room temperature without vacuum and no other carrier gas was used. No additional chemical was used in the thermal liquefaction phase. The fuel is filtered RCI purification using a fuel filter that operates using coalescence and centrifugal force.

Table2: GC/MS Chromatogram Compounds list of PS Raw Waste Plastic

Retention Time (M)	Compound Name	Compound Formula	Retention Time (M)	Compound Name	Compound Formula
2.17	Cyclopropane	C ₃ H ₆	24.78	1,1'-Biphenyl, 3-methyl-	C ₁₃ H ₁₂
2.24	Methylenecyclopropane	C ₄ H ₆	25.64	1,2-Diphenylethylene	C ₁₄ H ₁₂
3.69	1,5-Hexadiyne	C ₆ H ₆	26.23	Benzene, 1,1'-(1-methyl-1,2-ethanediy)bis-	C ₁₅ H ₁₆
5.52	Toluene	C ₇ H ₈	27.30	1,2-Diphenylcyclopropane	C ₁₅ H ₁₄
5.64	1,5-Heptadien-3-yne	C ₇ H ₈	27.50	1,1'-Biphenyl, 4-ethenyl-	C ₁₄ H ₁₂
8.13	Ethylbenzene	C ₈ H ₁₀	28.38	Benzene, 1,1'-(1,3-propanediyl)bis-	C ₁₅ H ₁₆
9.40	Phenylethyne	C ₈ H ₆	29.34	Anthracene, 9,10-dihydro-	C ₁₄ H ₁₂
9.98	Benzene, 1,2,4-trimethyl-	C ₉ H ₁₂	29.90	Benzene, 1,1'-(1-butenylidene)bis-	C ₁₆ H ₁₆
10.55	Benzene, 2-propenyl-	C ₉ H ₁₀	30.76	Phenanthrene, 1-methyl-	C ₁₅ H ₁₂
10.75	Benzene, propyl-	C ₉ H ₁₂	31.21	Anthracene	C ₁₄ H ₁₀
11.60	Benzene, cyclopropyl-	C ₉ H ₁₀	31.74	Benzene, 1,1'-(1,3-butadienylidene) bis-	C ₁₆ H ₁₄
11.86	α-Methylstyrene	C ₉ H ₁₀	31.77	1,4-Diphenyl-1,3-butadiene	C ₁₆ H ₁₄
12.86	Benzene, 2-propenyl-	C ₉ H ₁₀	32.51	Naphthalene, 1-phenyl-	C ₁₆ H ₁₂
13.39	1-Propyne, 3-phenyl-	C ₉ H ₈	32.69	Phenanthrene, 1-methyl-	C ₁₅ H ₁₂
13.71	1-Propyne, 3-phenyl-	C ₉ H ₈	33.05	Bicyclo[2.1.1]hexane, 1,4-diphenyl-	C ₁₈ H ₁₈
15.34	Benzene, 1,3-diethenyl-	C ₁₀ H ₁₀	33.25	Naphthalene, 1,2-dihydro-4-phenyl-	C ₁₆ H ₁₄
16.34	1H-Indene, 3-methyl-	C ₁₀ H ₁₀	33.74	Phenanthrene, 1-methyl-	C ₁₅ H ₁₂
16.60	Naphthalene	C ₁₀ H ₈	34.70	2-Phenylnaphthalene	C ₁₆ H ₁₂
16.80	Naphthalene, 1,2-dihydro-	C ₁₀ H ₁₀	35.21	1,5-Diphenyl-1,5-hexadiene	C ₁₈ H ₁₈
20.09	1,4-Methanonaphthalene, dihydro-	1,4-C ₁₁ H ₁₀	37.35	Naphthalene, 1-(phenylmethyl)-	C ₁₇ H ₁₄
20.28	Benzocycloheptatriene	C ₁₁ H ₁₀	37.63	p-Terphenyl	C ₁₈ H ₁₄
20.67	Naphthalene, 1-methyl-	C ₁₁ H ₁₀	38.79	Fluoranthene, 2-methyl-	C ₁₇ H ₁₂
22.32	Biphenyl	C ₁₂ H ₁₀	39.83	Benzene, 1,1'-[1-(ethylthio)propylidene]bis-	C ₁₇ H ₂₀ S
23.52	Diphenylmethane	C ₁₃ H ₁₂	40.13	Benzene, 1,1',1'',1'''-(1,2,3,4-butanetetrayl)tetrakis-	C ₂₈ H ₂₆

Small-scale waste plastic conversion tests have been performed with the simplified process shown in Figure.3; on two types of waste plastic types: Polypropylene (PP, code 5) and polystyrene (PS, code 6). These plastic types were investigated singly and in combination with other plastic types. In the laboratory scale process, the weight of a single batch of input plastic for the fuel production process ranges from 200 to 300 gram. The plastics are collected, optionally sorted, cleaned of contaminants, and cut or divided into small pieces 2-3mm prior to the thermal liquefaction process.

It should be noted here that the liquefaction process was used of 50% PP and 50% PS mixtures of waste plastic types with 5% activated carbon. Activated carbon was used to clean or removed dye from fuel. Total experiment runs time was 4-5 hours. 13-14kWh electricity required for one gallon fuel production. Activated carbon is removing dye waste plastic to fuel production period, dye are using during waste plastics production period. For visual understanding purpose Figure.4 is showing between 2 types of fuels color with activated carbon to fuel and without activated carbon to fuel from PP and PS mixture waste plastics. Activated carbon was used as a filter and this activated carbon is not come out with fuel and its remaining as a residue. Fuel density is 0.80gm/ml. In mass balance calculation showed 300gm of waste plastics to liquid fuel was 255gm, light gas generated 24gm, and solid black residue was 21 gm. PS waste plastic has high percentage of additives then PP waste plastic and all additives are coming as residue.

FT-IR (Fourier Transform Infra-red Spectroscopy) Spectrum-100, (Perkin Elmer) was used to fuel analysis (Figure.5 and table.3) purposes. FTIR program was set up elaborated before sample run and visible ray range were 4000-400cm⁻¹, NaCl cell was 0.05mm, scan number was 32 and resolution number was 4. FT-IR analysis of 50% PP, and 50% PS mixture waste plastic to fuel, following types of functional group are appeared such as wave number 2841.25cm⁻¹, functional group is CH₂/C-CH₃, continuously wave number 1871.89cm⁻¹, 1816.57cm⁻¹, 1798.97cm⁻¹, 1744.06cm⁻¹, 1685.07cm⁻¹, 1630.83 cm⁻¹ compound is Non-Conjugated, wave number 1576.16cm⁻¹, compound is conjugated, wave number 1440.26cm⁻¹, compound is CH₃, wave number 907.46cm⁻¹, compound is -CH=CH₂, wave number 729.12cm⁻¹ and 698.93cm⁻¹, compound is -CH=CH- (cis) respectively see Figure.5 and table.3. In fuel spectrum each compounds wave number band energy calculated accordingly. These are as follows, functional group CH₂/C-CH₃, energy value is 5.64x10⁻²⁰ J, functional group C-CH₃, energy value is 5.41x10⁻²⁰ J, functional group Non-conjugated, energy value is 3.71x10⁻²⁰ J, functional group conjugated, energy value is 3.3x10⁻²⁰ J, functional

group CH₃, energy value is 2.86x10⁻²⁰ J, Secondary Cyclic Alcohol, energy value is 1.80x10⁻²⁰ J and ultimately functional group -CH=CH- (cis) energy value is 1.37x10⁻²⁰ J correspondingly.

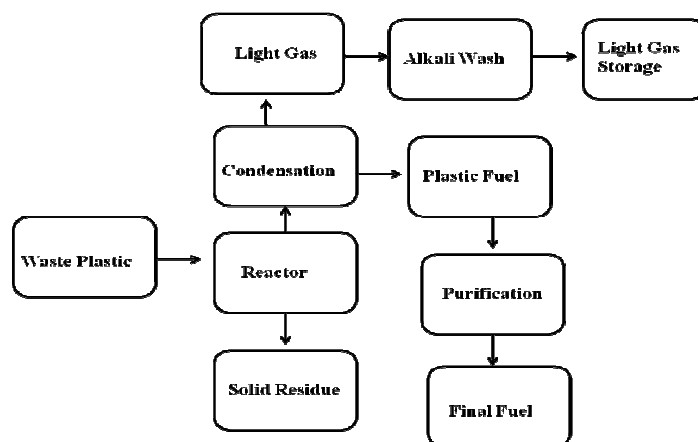


Figure.3: PP and PS mixture waste plastic to fuel production process with activated carbon



Figure.4: PP and PS waste plastic mixture to fuel with activated carbon (Yellow color) and PP and PS waste plastic to fuel without activated carbon (Brown color)

RESULT AND DISCUSSION

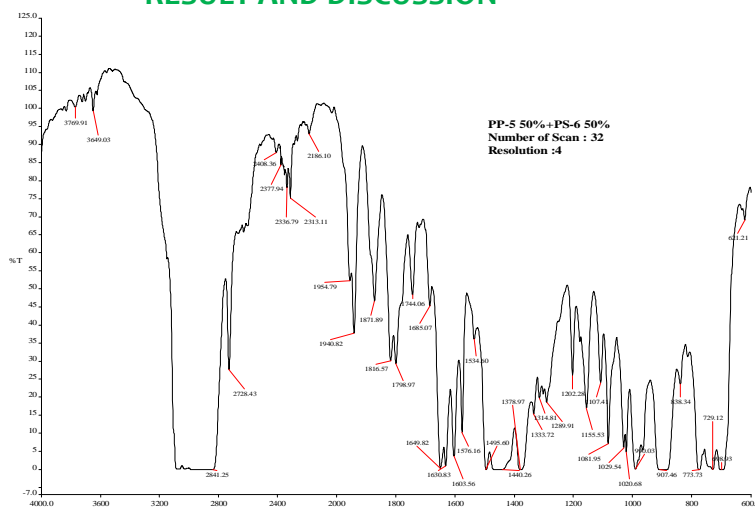


Figure.5: FT-IR spectrum of PP and PS waste Plastic to fuel

Table.3: FT-IR spectrum wave number and functional group list of PP and PS waste Plastic to fuel

Number of Wave	Wave Number (cm ⁻¹)	Functional Group
3	2841.25	CH ₂ / C-CH ₃
4	2728.43	C-CH ₃
12	1871.89	Non-Conjugated
13	1816.57	Non-Conjugated
14	1798.97	Non-Conjugated
15	1744.06	Non-Conjugated
16	1685.07	Non-Conjugated
17	1649.82	-Amides
18	1630.83	Non-Conjugated
20	1576.16	Conjugated
23	1440.26	CH ₃
33	990.03	Secondary Cyclic Alcohol
34	907.46	-CH=CH ₂
37	729.12	-CH=CH- (cis)
38	698.93	-CH=CH- (trans)

FT-IR (Fourier Transform Infra-red Spectroscopy) Spectrum-100, (Perkin Elmer) was used to fuel analysis (Figure.5 and table.3) purposes. FTIR program was set up elaborated before sample run and visible ray range were 4000-400 cm⁻¹, NaCl cell was 0.05 mm, scan number was 32 and resolution number was 4. FT-IR analysis of 50% PP and 50% PS mixture waste plastic to fuel, following types of functional group are appeared such as wave number 2841.25cm⁻¹, functional group is CH₂ / C-CH₃, continuously wave number 1871.89cm⁻¹, 1816.57cm⁻¹, 1798.97cm⁻¹, 1744.06cm⁻¹, 1685.07cm⁻¹, 1630.83cm⁻¹ compound is Non-Conjugated, wave

number 1576.16cm⁻¹, compound is conjugated, wave number 1440.26cm⁻¹, compound is CH₃, wave number 907.46cm⁻¹, compound is -CH=CH₂, wave number 729.12 cm⁻¹ and 698.93cm⁻¹, compound is -CH=CH- (cis) respectively see Figure.5 and table.3. In fuel spectrum each compounds wave number band energy calculated accordingly. These are as follows, functional group CH₂/C-CH₃, energy value is 5.64x10⁻²⁰ J, functional group C-CH₃, energy value is 5.41x10⁻²⁰ J, functional group Non-conjugated, energy value is 3.71x10⁻²⁰ J, functional group Conjugated, energy value is 3.3x10⁻²⁰ J, functional group CH₃, energy value is 2.86x10⁻²⁰ J, Secondary Cyclic Alcohol, energy value is 1.80x10⁻²⁰ J and ultimately functional group -CH=CH- (cis) energy value is 1.37x10⁻²⁰ J correspondingly.

PP & PS mix Fuel FTIR library search results was. sp/ mirlib. dlb Euclidean Search Hit List
 0.478 F91080 TRICHLOROACETONITRILE,
 0.470 F37460 2, 5-DIHYDROXYACETOPHENONE,
 0.399 F65470 3-METHYLACETOPHENONE,
 0.389 F65155 2-METHOXYPHENYLACETONITRILE,
 0.327 F54150 2-HYDROXYACETOPHENONE,
 0.307 F64700 2-METHOXYACETOPHENONE,
 0.301 F22850 4-CHLOROACETOPHENONE,
 0.298 F38558 3, 4-DIMETHOXYACETOPHENONE,
 0.294 F00508 ETHYL ACETOHYDROXAMATE,
 0.259 F24110 ETHYL 4-CHLORO-2 CYANOACETO ACETATE,

Table4: GC/MS Chromatogram compounds list of PP and PS waste plastic mixture to fuel

Number of Peak	Retention Time (M)	Compound Name	Compound Formula	Molecular weight	GC/MS ppm Level
1	1.52	Cyclopropane	C ₃ H ₆	42	11205.27
2	1.63	1-Propene, 2-methyl-	C ₄ H ₈	56	32702.98
3	1.95	Pentane	C ₅ H ₁₂	72	1.45
4	2.36	Pentane, 2-methyl-	C ₆ H ₁₄	86	117.47
5	2.52	3-Hexene, (Z)-	C ₆ H ₁₂	84	23231.76
6	3.00	2,4-Hexadiene, (Z,Z)-	C ₆ H ₁₀	82	29700.77
7	3.11	1-Pentene, 2,4-dimethyl-	C ₇ H ₁₄	98	58982.61
8	3.21	2,4-Dimethyl 1,4-pentadiene	C ₇ H ₁₂	96	84486.42
9	3.82	1,3-Pentadiene, 2,4-dimethyl-	C ₇ H ₁₂	96	10078.55
10	4.66	3-Heptene, 4-methyl-	C ₈ H ₁₆	112	10139.57
11	4.88	Toluene	C ₇ H ₈	92	87932.11
12	5.99	Cyclohexane, 1,3,5-trimethyl-	C ₉ H ₁₈	126	95021.91
13	6.10	2,4-Dimethyl-1-heptene	C ₉ H ₁₈	126	73759.89
14	6.50	Ethylbenzene	C ₈ H ₁₀	106	71502.16
15	7.08	Styrene	C ₈ H ₈	104	26185.27
16	7.57	Benzene, (1-methylethyl)-	C ₉ H ₁₂	120	95337.12
17	8.58	α-Methylstyrene	C ₉ H ₁₀	118	45113.79
18	8.99	Nonane, 2,6-dimethyl-	C ₁₁ H ₂₄	156	13607.06
19	9.70	2-Undecanethiol, 2-methyl-	C ₁₂ H ₂₆ S	202	62447.96
20	9.80	Bicyclo [3.1.0] hex-3-en-2-ol, 2-methyl-5-(1-methylethyl)-, (1α,2α,5α)-	C ₁₀ H ₁₆ O	152	39306.87
21	10.07	Cyclooctane, 1,4-dimethyl-, trans-	C ₁₀ H ₂₀	140	15612.67
22	10.14	1-Decene, 2,4-dimethyl-	C ₁₂ H ₂₄	168	32566.03
23	10.82	3-Tridecene, (E)-	C ₁₃ H ₂₆	182	1438.15
24	10.92	1-Dodecanol, 3,7,11-trimethyl-	C ₁₅ H ₃₂ O	228	4884.58
25	11.14	Benzene, (3-methyl-3-butenyl)-	C ₁₁ H ₁₄	146	90285.35
26	11.20	(2,4,6-Trimethylcyclohexyl) methanol	C ₁₀ H ₂₀ O	156	26892.86

27	12.45	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	4197.48
28	12.68	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	8346.36
29	13.47	1-Nonene, 4,6,8-trimethyl-	$C_{12}H_{24}$	168	67907.60
30	13.83	Benzene, heptyl-	$C_{13}H_{20}$	176	69582.99
31	14.07	1-Nonene, 4,6,8-trimethyl-	$C_{12}H_{24}$	168	3272.27
32	14.37	9-Eicosene, (E)-	$C_{20}H_{40}$	280	142.54
33	14.80	8-Phenyl-1-octanol	$C_{14}H_{22}O$	206	187.78
34	15.88	Disulfide, di-tert-dodecyl	$C_{24}H_{50}S_2$	402	27697.50
35	16.32	1-Hexadecanol, 3,7,11,15-tetramethyl-	$C_{20}H_{42}O$	298	40323.66
36	16.65	Trichloroacetic acid, hexadecyl ester	$C_{18}H_{33}Cl_3O_2$	386	7553.57
37	17.19	2,4,6-Trimethylcyclohexyl) methanol	$C_{10}H_{20}O$	156	24291.23
38	18.19	Benzene, 1,1'-(1,3-propanediyl)bis-	$C_{15}H_{16}$	196	09838.13
39	18.50	Benzene, 1,1'-(1-methyl-1,3-propanediyl)bis-	$C_{16}H_{18}$	210	759.07
40	18.82	1-Nonadecene	$C_{19}H_{38}$	266	2158.16
41		Benzene, 1,1'-[1-(2,2-dimethyl-3-butenyl)-1,3-propanediyl]bis-	$C_{21}H_{26}$	278	41519.40
42	19.62	Cyclododecanemethanol	$C_{13}H_{26}O$	198	0.38
43	21.06	1-Hexadecanol, 3,7,11,15-tetramethyl-	$C_{20}H_{42}O$	298	2213.46
44	21.75	Naphthalene, 2-phenyl-	$C_{16}H_{12}$	204	90287.71
45	25.87	(2,3-Diphenylcyclopropyl)methyl phenyl sulfoxide, trans-	$C_{22}H_{20}OS$	332	15874.21

Product fuel was analyzed by gas chromatography and mass spectrometer (GC/MS) and solvent was carbon disulfide (C_2S) and chromatogram and compounds table shown Figure.6 and table.4. For analysis purposed GC column was used Perkin Elmer elite-5MS length 30 meter, 0.25 mm ID, 0.5um df, maximum program temperature was 350°C and minimum bleed at 330°C (cat.# N9316284) and also it can be used -60°C. Capillary column internal silica coating of viscous liquid such as carbowax or wall bonded organic materials. GC/MS operational purpose carrier gas was as a Helium gas. For GC method was setup initial temperature 40°C and initial hold for 1 minute. Final temperature setup was 330°C. Temperature ramping rate was 10°C/minutes up to 325°C and hold for 15 minutes 325°C. Total experiment runs time was 44.50 minutes. MS method setup for sample analysis MS scan time was 1 to 44.50 minutes and mass detection range was 35- 528 EI+ centroid. Internal scan time was used 0.15 second. Mass detection was creating m/z ratio.

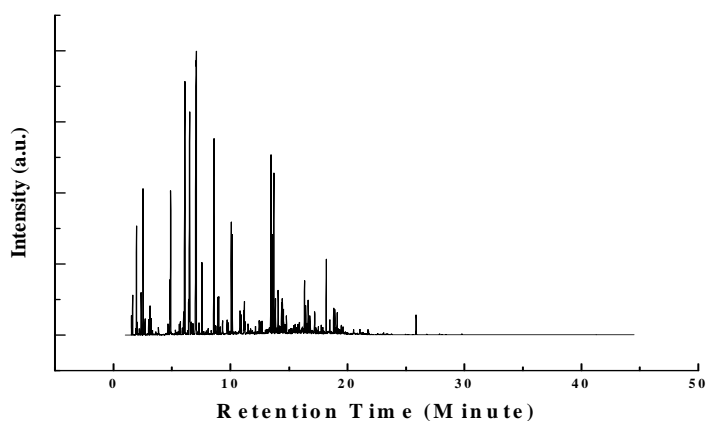


Figure.6: GC/MS Chromatogram of PP and PS waste plastic mixture to fuel

From GCMS analysis chromatogram Figure.6 and compounds table.4 shown at peak intensity 4% initial compound is Cyclopropane, retention time is 15.2, molecular formula is C_3H_6 , molecular weight is 42, and ppm level concentration is 11205.27. Peak intensity 53% showing aromatic group compound that is Toluene, retention time is 4.88, molecular formula C_7H_8 , molecular weight is 92 and ppm level concentration is 87932.11. From this fuel chromatogram 100% peak intensity compound is called Styrene, molecular formula is C_8H_8 and molecular weight is 104, ppm level is 26085.27. In retention time 18.19 benzene group compound benzene, 1,1-(1,3-propanediyl) bis-, molecular formula is $C_{15}H_{16}$, molecular weight is 196 and ppm level is 09338.13 as well peak intensity is 28%. From this chromatogram at the end compound comes out that is (2,3-Diphenylcyclopropyl) methyl phenyl sulfoxide, trans-, peak intensity is 5%, molecular structure is $C_{22}H_{20}OS$, molecular weight is 332, ppm level is 15874.21. It is noticeable that in this GCMS chromatogram contains single bond compound that's alkane, double bond compound that's alkenes and aromatic compound that's benzene group compound as well as with different retention time. Product fuel compounds ppm level was comparison with restek standard hydrocarbon compounds. Product fuel has hydrocarbon compounds including aromatic compounds, oxygen content compounds and alcoholic compounds. Product fuel has benzene related compounds concentration and all aromatics compounds are come from polystyrene waste plastic.

Waste polypropylene and polystyrene plastic to fuel was analysis by DSC for fuel enthalpy value determination and graph shown Figure.7. DSC program temperature was setup range from 10- 400°C, temperature ramping rate was 10°C/ minute and carrier gas was N_2 . From DSC analysis result found that PP and

PS mixture to product fuel onset temperature is 132.23°C, height peak temperature is 155.56 °C, enthalpy Delta H value = 16780.8296 J/g.

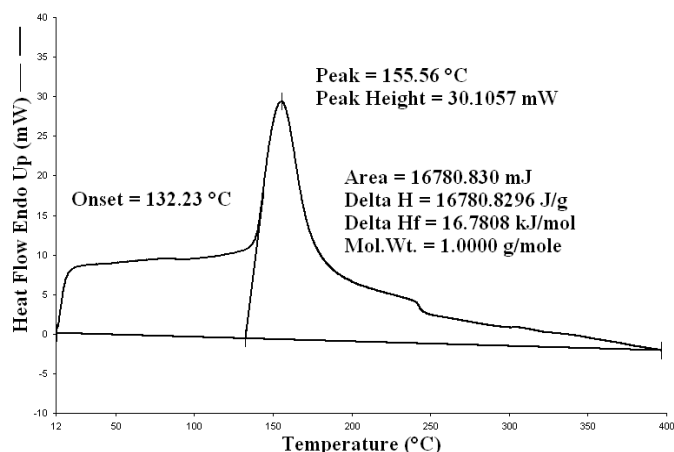


Figure.7: Differential Scanning Calorimeter (DSC) graph of PP and PS waste plastic mixture to fuel

CONCLUSION

Polypropylene and polystyrene waste plastics mixture to fuel production process was under laboratory fume hood in batch process. Temperature range was 25°C to 450°C. Product fuel was analysis GC/MS, FT-IR and DSC for fuel compounds, functional group, and enthalpy value determination. GC/MS analysis result showed fuel carbon chain C₃-C₂₂ and product fuel has high concentration aromatic compounds such as Toluene, Styrene, α -Methylstyrene, (3-methyl-3-butenyl)-Benzene, heptyl-Benzene, bis-1, 1'-(1-methyl-1, 3-propanediyl) Benzene, 2-phenyl-Naphthalene and so on. Aromatic group can increase fuel efficiency and combustion engine knock capacity. Fuel ignited and color was light yellow. Fuel density is 0.80g/ml and fuel was use combustion engines and diesel engine for electricity generation. Waste plastics are creating various sorts of environmental and health related problems in the world today. The management of waste plastics is very expensive. The disposal of waste plastics require large amount of land and sometimes they end up in the ocean. A simple thermal degradation process for de-polymerizing waste plastics to hydrocarbon fuel energy categories has been developed. This method can reduce or overall eliminate the problems of waste plastics. Commercialized, the technology will address the energy crisis and also environmental safety issues by reducing harmful waste plastics from landfill and converting them into valuable hydrocarbon fuel sources of energy. The fuel has high heat capacity, and has been shown to successfully

power generators, diesel generator, a gas-powered lawn mower and an automobile.

ACKNOWLEDGEMENT

The authors acknowledge the support of **Dr. Karin Kaufman**, the founder and sole owner of Natural State Research, Inc. The author also acknowledges the valuable contributions NSR laboratory team members during the preparation of this manuscript.

REFERENCES

1. Manjula M, Ibrahim and Mohindar S Seehra, Sulfur-Promoted Degradation of Polyethylene/ Polypropylene Detected by Electron Spin Resonance Spectroscopy Energy & Fuels 1997, 11, 926-930.
2. Paul T, Williams and Elizabeth A Williams, Interaction of Plastics in Mixed-Plastics Pyrolysis, Energy & Fuels 1999, 13, 188-196.
3. Rashid Khan M, Gorsuch CA, In Conversion and Utilisation of Waste Materials; Rashid Khan M, Ed.; Taylor and Francis Publications: Washington, DC, 1996.
4. Franklin Associates, Characterization of Municipal Solid Waste in the United States: 1998 Update; U.S. Environmental Protection Agency, U.S. Government Printing Office: Washington, D.C., 1999.
5. Jose M Arandes, Inaki Abajo, Danilo Lopez-Valerio, Inmaculada Fernandez, Miren J Azkoiti, Martin Olazar and Javier Bilbao, Transformation of Several Plastic Wastes into Fuels by Catalytic Cracking, Ind. Eng. Chem. Res. 1997, 36, 4523-4529.
6. Source: web site of the Association of Plastic Manufacturers of Europe.
7. Grammelis P, P Basinas, A Malliopoulou, G Sakellariopoulos, Pyrolysis kinetics and combustion characteristics of waste recovered fuels, Fuel, 88, 2009, 195-205.
8. Kiran N, Ekinci E, Snape CE, Recycling of plastic wastes via pyrolysis, Resources, Conservation and Recycling, 29, 2000, 273-283.
9. Jerzy Walendziewski, Mieczysław Steiningier, Thermal and catalytic conversion of waste polyolefines, Catalysis Today, 65, 2001, 323-330.
10. McCaffrey WC, MR Kamal and DG Cooper, Thermolysis of polyethylene, Polymer degradation and stability, 47, 1995, 133-139.
11. Nnamso S Akpanudoh, Karishma Gobin, George Manos, Catalytic degradation of plastic waste to liquid fuel over commercial cracking catalysts Effect of polymer to catalyst ratio/acidity content, Journal of Molecular Catalysis A: Chemical, 235, 2005, 67-73.
12. Yeuh-Hui Lin, Production of valuable hydrocarbons by catalytic degradation of a mixture of post-consumer plastic waste in a fluidized-bed reactor, Polymer Degradation and Stability, 94, 2009, 1924-1931.

Source of support: Nil

Conflict of interest: None Declared