American Journal of Environment, Energy and Power Research
Vol. 2, No. 3, December 2014, pp. 1 - 10, ISSN: 2329 - 860X (Online)
Available online at www.ajeepr.com

Research article

Polypropylene Waste Plastic Conversion into Fuel Oil by using Thermal Degradation with Fractional Process

Moinuddin Sarker*, Mohammad Mamunor Rashid

Natural State Research, Inc. Department of Research and Development, 191C, Route 22.
Pawling, NY-12564, USA.

*E-mail: msarker@naturalstateresearch.com, mamun_sarker2004@yahoo.com

---

Abstract

Worldwide PP waste plastic is generating almost 14% from total waste plastics generation. Plastic usage percentage is increasing rapidly. After usage plastic become waste plastic and through into land fill. Polypropylene (PP) waste plastic to heavy fuel oil production thermal degradation process was study without catalyst. Thermal degradation temperature was used for PP waste plastic liquefaction range 120-400 ºC and fractional distillation column temperature was used for heavy grade fuel collection temperature range was 340-365 ºC. Produced fuel density is 0.80g/ml and Fuel analyze purposes Gas Chromatography and Mass Spectrometer was used for liquid fuel analysis and hydrocarbon range was C_4H_8 to $C_{35}H_{70}$ etc. Highest intensity peak compound from GC/MS showed 1-Nonadecanol ($C_{19}H_{40}O$). Produced fuel density is 0.81 g/ml. ASTM (American Standard and Testing Method) test determination sulfur content less than EPA level. Produced fuel BTU value was determination by ASTM test.

Keywords: waste plastic, polypropylene, conversion, fuel oil, thermal degradation, fractional column

---

1. Introduction

With a view to the environmental protection and reduction of non-regeneration resource, recycling technology for converting to oil from plastic wastes has drawn much attention in the world. Some universities and institutes have developed the basis theories and the technology for industrialization of plastic liquefaction. Many patents on the converting technology have been adopted. Many pilot plants have been built up in different part of the world. But some problems have appeared accordingly. Firstly, there being no effective collecting system and transportation and sorting the collected waste plastics simply by manual, as a result, the collected plastic wastes cannot satisfy the

continuous production on a large scale. Secondly, the secondary pollution has not been seriously considered in the process of waste plastics. The environmental considerations deals with heat energy waste exhaust gas emission, water and dust waste, and the like.

High temperature pyrolysis and cracking of waste thermoplastic polymers, such as polyolefines, polyethylene (PE), polypropylene (PP) and polystyrene (PS), are well known and environmentally accepted methods of their utilisation. This group of processes embraces thermal pyrolysis and cracking, catalytic cracking and hydrocracking in the presence of hydrogen. Pyrolysis is the typical chemical recycling process, enabling production of monomers, mainly ethylene, propene and butene from waste plastics. In case of cracking processes, their main products are fuels fractions, gaseous hydrocarbons and liquid mixtures of hydrocarbons boiling in the range of temperatures ~35–360 8C (gasoline and light gas oils) as well as the solid carbon residues, similar to coke. Numerous papers present the results of application of various acidic catalysts, such as silica–alumina, zeolites (HY, HZSM-5, mordenite) or alkaline compounds such as ZnO, CaO and K_2O (Uemichi Y et al, 1998; Ding W et al, 1997; Zhibo Z et al, 1996; Kargfz S et al , 2003;). An interesting method of polymers utilization is cracking, similar to the visbreaking of vacuum residue or catalytic cracking of vacuum gas oil (VGO) in the presence of various zeolites containing cracking catalysts (Songip A.R et al, 1994;). Some inventors propose cracking of melted polymers together with petroleum and carbon derived fractions or biomass with using of typical commercial and laboratory prepared catalysts (Kargfz S et al, 2003; Kastner H and Kaminsky W, 1995; De la Puente G et al, 1997; Serrano D.P et al, 2003; Lovett S et al, 1997; Arandes J.M et al, 2003; Pinto F et al, 2002;). In this type of the processes, application of catalyst of higher acidity (HY, ZSM-5, silica–alumina based catalysts) results mainly in C_5–C_{12} liquid hydrocarbons, while in case of thermal or process with the use of non-acid catalysts somewhat higher content of C_{12}–C_{22} compound was also found (Sakata Y et al, 1997;).

Among the plastic categories Polypropylene is one of the most abundant. It is used in every day application for many different purposes. Analysis utilizing Gas Chromatography and Mass Spectrometer and Thermo gravimetric analysis have shown that polypropylene has large number of hydrocarbon groups, which are linearly chained. Using thermal degradation to break down the large carbon groups to shorter carbon chain products are explained in this paper. The shorter chain hydrocarbons are represented by liquid hydrocarbon fuels which are flammable and combustible. The analysis of the products are also shown in this paper, the analysis have been performed utilizing Gas Chromatography and Mass Spectrometer (GC/MS), FT-IR Spectrum 100 and EA 2400 Elemental Analyzer. The results of these finding are presented in the study in comparison with commercial gasoline in the market.

2. Materials and Method

2.1 Materials

Polypropylene waste plastic collected from donut delight coffee store and PP waste plastic was hard transparent glass. PP waste plastic was come out with left over coffee. After collected PP coffee glasses were clean by using liquid soap and water. Then cut into small pieces and sent to grinder machine for reactor setup and grounded waste PP plastic size was ~ 4-5 mm.

2.2 Experimental Process

Polypropylene (PP) waste plastic to heavy grade fuel oil production process plastic sample was used 500 gm into glass reactor showed into **figure 1** (patent pending**)**. Figure 1 specification was given by number wise 1 = polypropylene waste plastic, 2= Glass reactor, 3 = Fractional distillation column, 4= 1st fraction temperature, 5= 2nd fraction temperature, 6=3rd fraction temperature, 7= 4th fraction temperature, 8= 5th fraction temperature, 9= light gas cleaning system, 10= 1st fraction fuel collection tank, 11=2nd fraction fuel collection tank, 12=3rd fraction fuel

collection tank, 13=4th fraction fuel collection tank, 14 = 5th fraction fuel collection tank, 15 = small pump, 16 = Teflon bag for light gas storage. Rector temperature can go up to 450 ºC and temperature was monitored by variac meter for temperature increase and decrease. Reactor was connected with fractional distillation column and temperature profile set up 1st fractional to 5th fractional. Experimental main goal was 5th fractional fuel collection or heavy fuel oil collection. Whole process was setup under laboratory fume hood and process was fully closed system. After finished experimental process setup heat start from 100 ºC to 400 ºC gradually. Chemical or catalyst did not apply in this experiment. When temperature increased from 100 ºC to 250 ºC then plastic was melt and creates vapor and some vapor come out. This experiment did not apply vacuum system when experiment was setup. Some moisture was present inside system and moisture was come out with vapor. Melted waste PP plastic when become fully liquid slurry due to heat increase from 250 ºC to 300 ºC the liquid slurry to turn into vapor at the end vapor travel through fractional column and collected different grade liquid fuel with different percentage. 5th fractional heavy fuel was collected from fractional distillation column and temperature was 340 – 365 ºC. Fuel production was continued until temperature 400 ºC and it took time for experiment 5:30 hours. Collected all grade fuel was kept into separate container. 5th fractional fuel or heavy fuel percentage was 15% and rest of other grade was 80%, light gas and residue percentage was 3% and 2%. Collected fuel was purified by using RCI centrifugal purification system for removed contamination from liquid fuel. Light gas was cleaned by alkali solution wash and transfer into Teflon bag for future use and light gas content was alkane or alkene group such as methane, ethane, propane and butane.

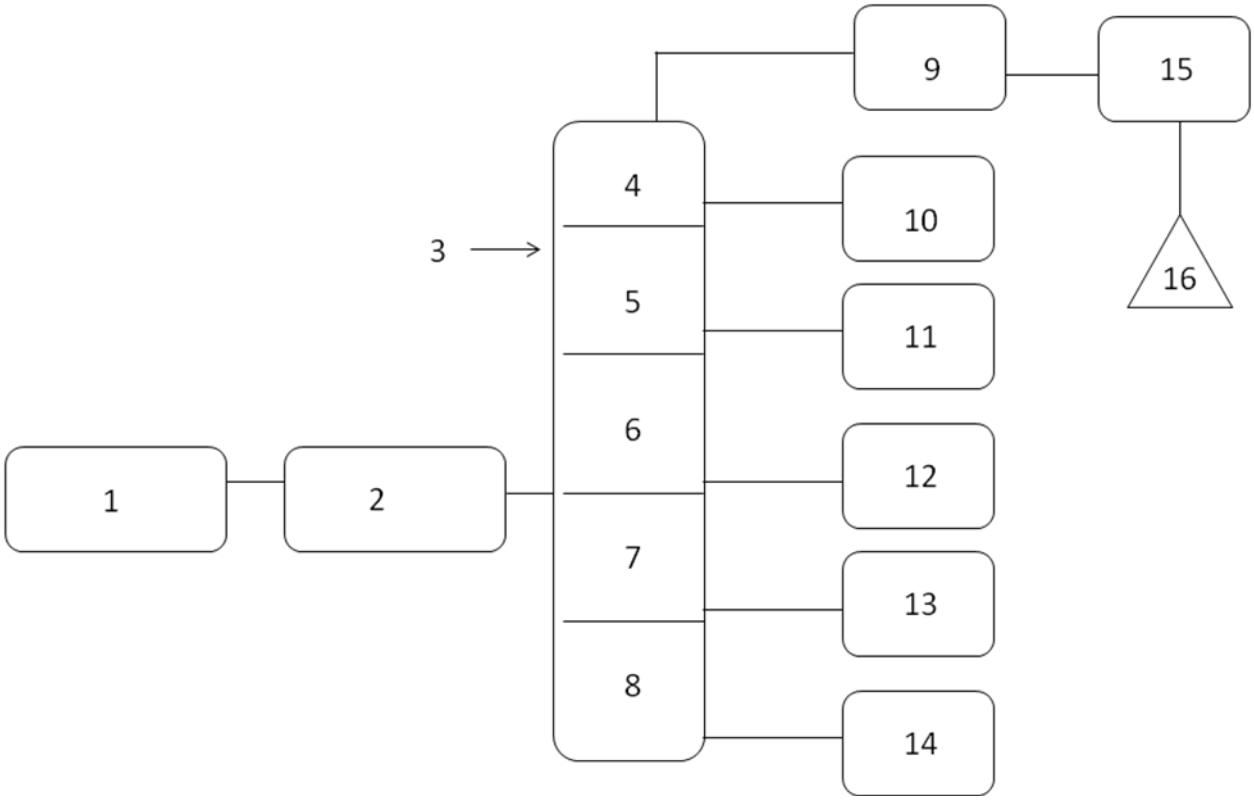

Figure 1: Polypropylene waste plastic to fuel oil production process

(1 = polypropylene waste plastic, 2= Glass reactor, 3 = Fractional distillation column, 4= 1st fraction temperature, 5= 2nd fraction temperature, 6=3rd fraction temperature, 7= 4th fraction temperature, 8= 5th fraction temperature, 9= light

gas cleaning system, 10= 1st fraction fuel collection tank, 11=2nd fraction fuel collection tank, 12=3rd fraction fuel collection tank, 13=4th fraction fuel collection tank, 14 = 5th fraction fuel collection tank, 15 = small pump, 16 = Teflon bag for light gas storage).

3. Results and Discussion

Produced fuel was analyzed by using Differential Scanning Calorimeter (DSC) for boiling point measuring. PP waste plastic to heavy fuel oil (see **fig. 2**) production temperature range is 340 -365ºC. This produce fuel has heavier hydrocarbon compound. This fuel heavy and thick and fuel quality similar to fuel oil this fuel use only heavy equipment such as big ship and freight. This fuel density is 0.81 g/ml. Produced fuel analysis by DSC and for analysis purpose sample was use only 50 micro liter. From fuel graph analysis X1= 5.51 ºC and Y1= 0.1225 mW. Fuel boiling point temperature showed from graph is 241.17 ºC and onset temperature is 235.87 ºC. Heat enthalpy value delta H is 43245.8014 J/g and area of graph 43245.801 mJ. Fuel graph end temperature 235.87 ºC and X2=393.50, Y2= 13.1311mW. Fuel analysis percentage was at 50 ºC 12.66%, 150 ºC 51.81% and finally 393.36 ºC was 100%.

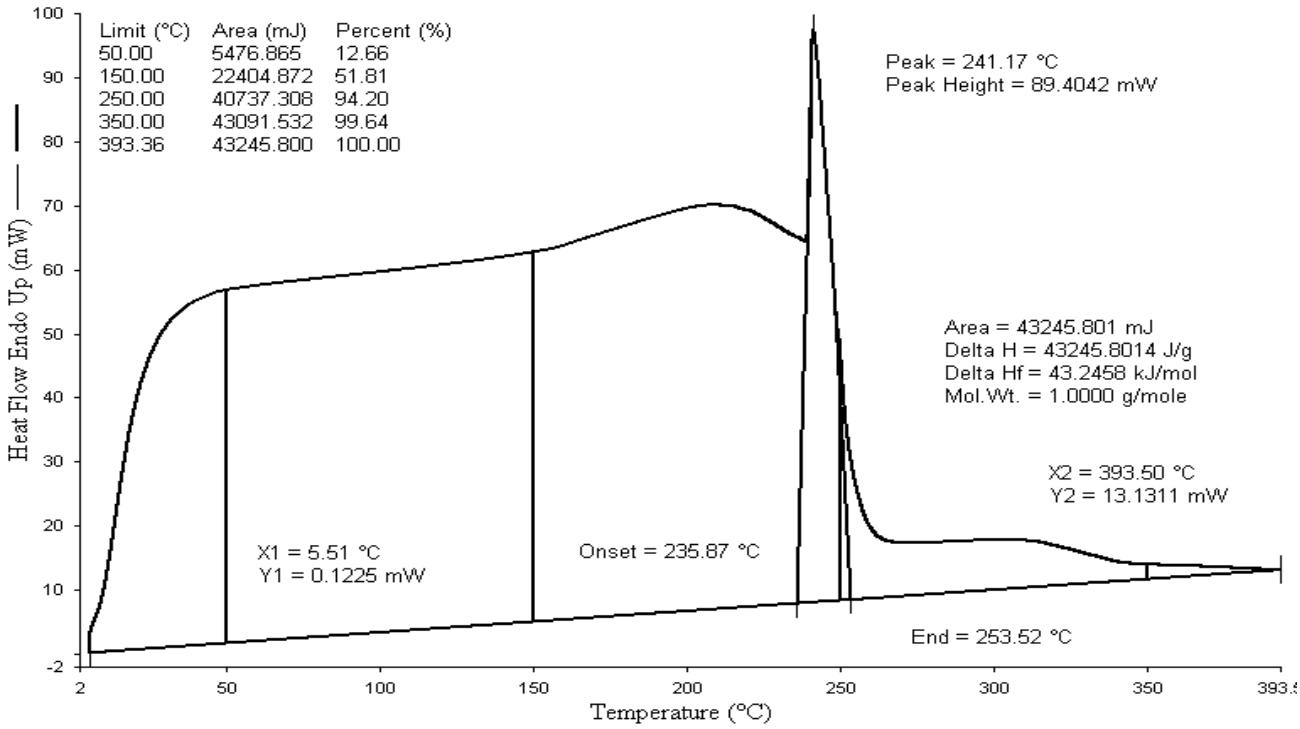

Figure 2: DSC graph of PP waste plastic to fuel oil

Table 1: PP waste plastic to fuel oil functional group name

Number of Wave	Wave Number cm^{-1}	Functional Group Name	Number of Wave	Wave Number cm^{-1}	Functional Group Name
1	3349.14	Intermolecular H bonds	6	1650.74	Non-Conjugated
2	2942.95	C-CH_3	7	1455.11	CH_2

3	2726.58	$C-CH_3$	8	888.33	$C=CH_2$
4	1780.56	Non-Conjugated	9	1031.87	Acetates
5	1720.78	Non-Conjugated	10	738.61	-CH=CH-(cis)

Perkin Elmer FT-IR (Spectrum 100) was used for analysis of PP waste plastic to fuel oil (**fig. 3 and table 1**) according to their wave number and spectrum band following types of functional groups are appeared in the analysis. In the spectrum field noticed that higher wave number are emerged in the initial phase and middle index of the spectrum and in higher wave number small and bulky both functional groups are available and in low wave number double bond and single bond functional groups are available such as methane group, cis and trans alkene etc. Hereafter wave number wave number 3349.14 cm^{-1} functional group is Intermolecular H bonds, wave number 2942.95 cm^{-1} and 2726.58 functional group is $C-CH_3$, wave number 1780.56 cm^{-1},1720.78 cm^{-1} and 1650.74 cm^{-1} functional group is Non-Conjugated, wave number 1455.11 cm^{-1} functional group is CH_2, wave number 883.33 cm^{-1} functional group is $C=CH_2$, wave number 1031.87 cm^{-1} functional group is Acetates and ultimately wave number 738.61 cm^{-1} functional group is -CH=CH-(cis) respectively. Some wave number band energy are calculated and elaborated them accordingly such as wave number 3349.14 cm^{-1} band energy is 6.65 X 10^{-20} J, wave number 2942.95 cm^{-1} band energy is 5.85 X 10^{-20} J, 2726.58 cm^{-1} wave number band energy is 5.41 X 10^{-20} J and finally wave number 1720.78 cm^{-1} band energy is 3.41 X 10^{-20} J and this values reflect with calorific value.

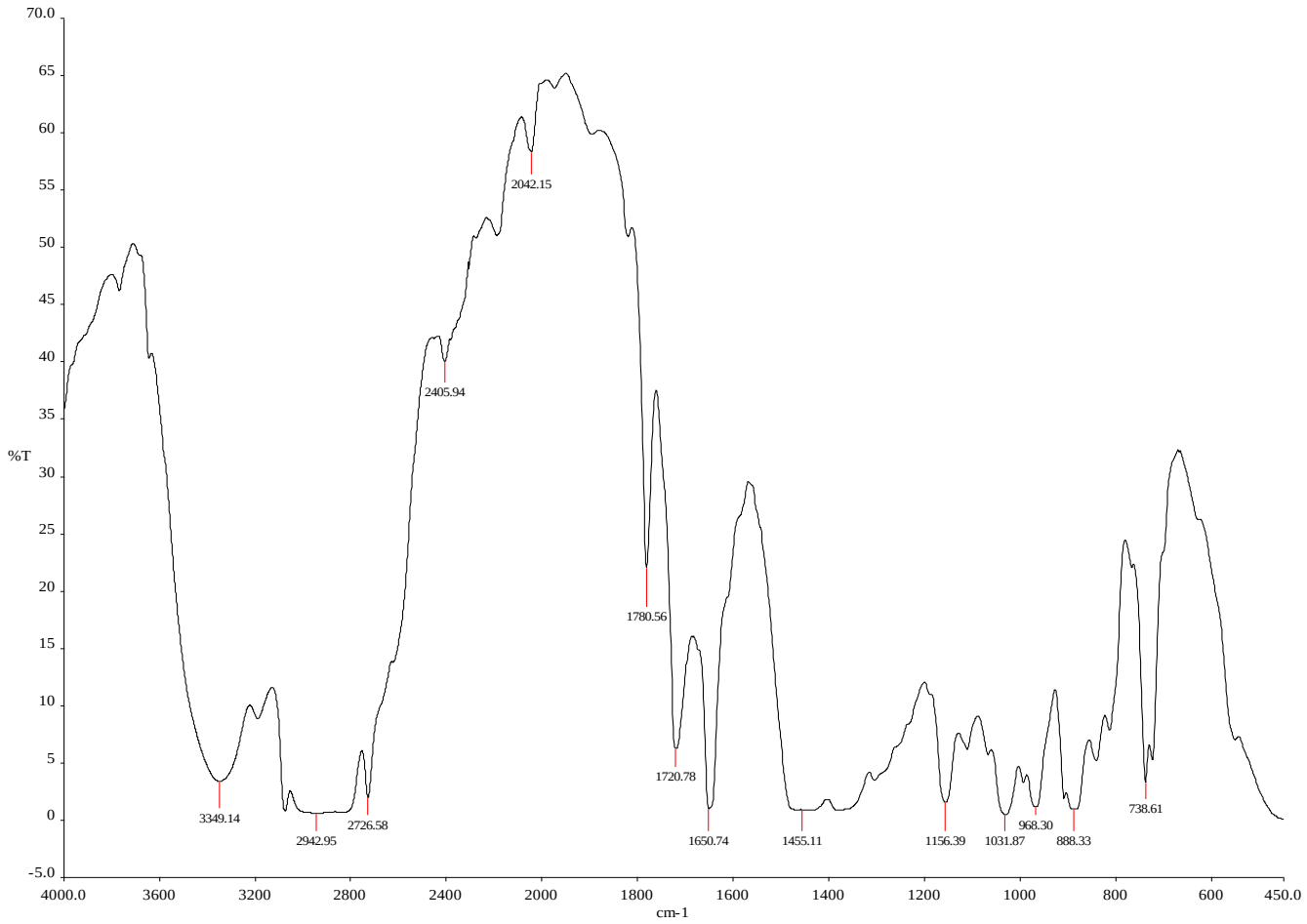

Figure 3: FT-IR Spectrum of PP waste plastic to fuel oil

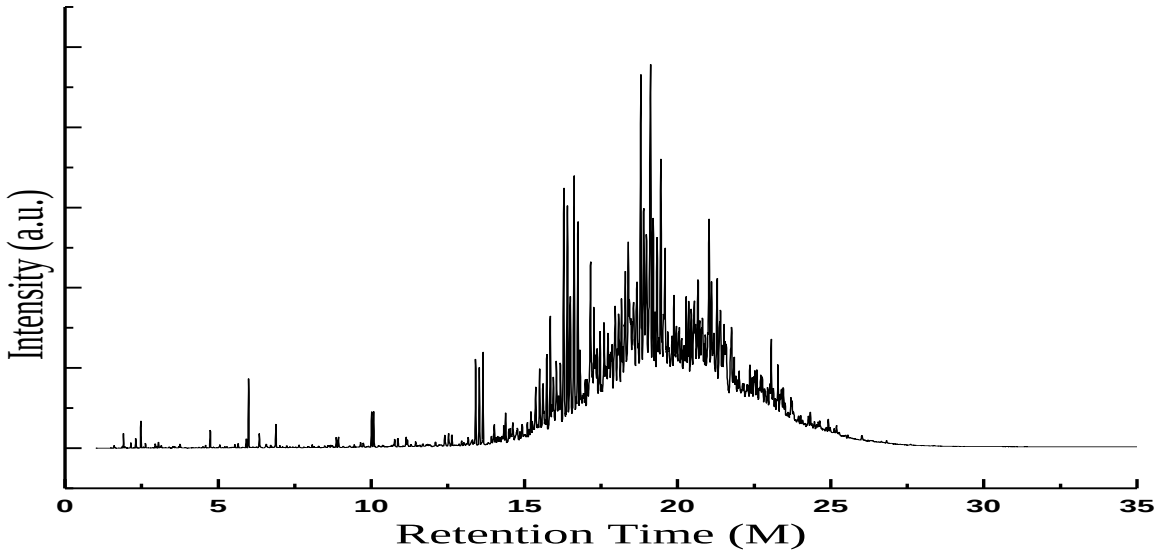

Figure 4: GC/MS Chromatogram of PP waste plastic to fuel oil

Table 2: GC/MS Chromatogram of PP waste plastic to fuel oil compound list

Peak Number	Retention Time (min.)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	CAS Number
1	1.60	41	1-Propene, 2-methyl-	C_4H_8	56	23.7	115-11-7
2	1.91	43	Pentane	C_5H_{12}	72	83.7	109-66-0
3	1.95	55	Cyclopropane, 1,2-dimethyl-, cis-	C_5H_{10}	70	17.4	930-18-7
4	2.31	43	Pentane, 2-methyl-	C_6H_{14}	86	34.2	107-83-5
5	2.48	41	1-Pentene, 2-methyl-	C_6H_{12}	84	28.2	763-29-1
6	2.63	69	2-Pentene, 4-methyl-, (Z)-	C_6H_{12}	84	19.0	691-38-3
7	2.94	67	Isopropenylcyclopropane	C_6H_{10}	82	9.40	4663-22-3
8	2.99	67	1,3-Pentadiene, 2-methyl-, (E)-	C_6H_{10}	82	9.06	926-54-5
9	3.05	56	1-Pentene, 2,4-dimethyl-	C_7H_{14}	98	47.8	2213-32-3
10	3.11	55	2-Pentene, 3-ethyl-	C_7H_{14}	98	8.42	816-79-5
11	3.14	81	2,4-Dimethyl 1,4-pentadiene	C_7H_{12}	96	46.3	4161-65-3
12	3.28	41	Pentane, 2-bromo-2-methyl-	$C_6H_{13}Br$	164	5.93	4283-80-1
13	3.40	43	Hexane, 3-methyl-	C_7H_{16}	100	65.0	589-34-4
14	3.52	43	2-Pentanone	$C_5H_{10}O$	86	67.9	107-87-9
15	3.56	56	1-Hexene, 2-methyl-	C_7H_{14}	98	23.9	6094-02-6
16	4.74	43	Heptane, 4-methyl-	C_8H_{18}	114	64.7	589-53-7
17	5.91	69	Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5α)-	C_9H_{18}	126	27.0	1795-27-3
18	5.99	43	2,4-Dimethyl-1-heptene	C_9H_{18}	126	58.3	19549-87-2
19	6.34	69	Cyclohexane, 1,3,5-	C_9H_{18}	126	28.2	1795-26-2

			trimethyl-, (1α,3α,5β)-				
20	6.88	43	Dicyclopropyl carbinol	$C_7H_{12}O$	112	9.56	14300-33-5
21	8.86	43	Decane, 4-methyl-	$C_{11}H_{24}$	156	21.5	2847-72-5
22	8.93	43	Decane, 4-methyl-	$C_{11}H_{24}$	156	9.50	2847-72-5
23	10.01	41	3-Dodecene, (E)-	$C_{12}H_{24}$	168	4.06	7206-14-6
24	10.08	41	1-Octene, 3,7-dimethyl-	$C_{10}H_{20}$	140	3.50	4984-01-4
25	10.76	41	Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-, (1R-cis)-	$C_{11}H_{20}O$	168	4.14	59642-07-8
26	10.87	41	2-Undecanethiol, 2-methyl-	$C_{12}H_{26}S$	202	6.69	10059-13-9
27	11.14	69	2-Isopropenyl-5-methylhex-4-enal	$C_{10}H_{16}O$	152	3.80	75697-98-2
28	11.18	41	Pentanoic acid, 10-undecenyl ester	$C_{16}H_{30}O_2$	254	6.17	N/A
29	11.44	69	1-Isopropyl-1,4,5-trimethylcyclohexane	$C_{12}H_{24}$	168	11.5	219783-06-9
30	12.09	69	1b,5,5,6a-Tetramethyl-octahydro-1-oxa-cyclopropa[a]inden-6-one	$C_{13}H_{20}O_2$	208	10.2	N/A
31	12.40	43	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	14.5	192823-15-7
32	12.95	83	E-2-Hexadecacen-1-ol	$C_{16}H_{32}O$	240	4.22	N/A
33	13.02	43	4-Hydroxy-4-methylhex-5-enoic acid, tert.-butyl ester	$C_{11}H_{20}O_3$	200	4.74	N/A
34	13.41	43	Trifluoroacetic acid, n-heptadecyl ester	$C_{17}H_{31}F_3O_2$	324	3.27	N/A
35	13.53	43	1-Nonene, 4,6,8-trimethyl-	$C_{12}H_{24}$	168	3.04	54410-98-9
36	13.65	43	Isotridecanol-	$C_{13}H_{28}O$	200	2.78	27458-92-0
37	14.01	43	2-Undecanethiol, 2-methyl-	$C_{12}H_{26}S$	202	4.38	10059-13-9
38	14.33	43	2-Piperidinone, N-[4-bromo-n-butyl]-	$C_9H_{16}BrNO$	233	3.04	195194-80-0
39	14.39	55	E-2-Octadecadecen-1-ol	$C_{18}H_{36}O$	268	7.12	N/A
40	15.21	69	Undecane, 1,2-dibromo-2-methyl-	$C_{12}H_{24}Br_2$	326	4.66	55334-43-5
41	15.37	43	Tetradecane, 2,6,10-trimethyl-	$C_{17}H_{36}$	240	9.20	14905-56-7
42	15.50	43	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	14.7	192823-15-7
43	15.60	43	Tetradecane, 2,6,10-trimethyl-	$C_{17}H_{36}$	240	11.8	14905-56-7
44	15.73	43	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	10.3	192823-15-7
45	15.84	41	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242	5.07	2425-77-6
46	16.29	43	1-Octadecene	$C_{18}H_{36}$	252	5.38	112-88-9
47	16.75	83	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242	3.34	2425-77-6
48	17.16	69	9-Eicosyne	$C_{20}H_{38}$	278	5.67	71899-38-2
49	18.39	83	9-Tricosene, (Z)-	$C_{23}H_{46}$	322	4.46	27519-02-4
50	18.67	55	1-Nonadecanol	$C_{19}H_{40}O$	284	4.06	1454-84-8
51	19.45	55	1-Nonadecanol	$C_{19}H_{40}O$	284	6.22	1454-84-8
52	19.59	69	Phytol	$C_{20}H_{40}O$	296	7.49	150-86-7

53	19.88	55	1-Docosanol	$C_{22}H_{46}O$	326	5.43	661-19-8
54	20.28	57	Heptacosane	$C_{27}H_{56}$	380	6.02	593-49-7
55	20.37	43	Cyclopentane, (4-octyldodecyl)-	$C_{25}H_{50}$	350	5.35	5638-09-5
56	21.03	83	Acetic acid, 3,7,11,15-tetramethyl-hexadecyl ester	$C_{22}H_{44}O_2$	340	5.50	N/A
57	21.11	83	9-Tricosene, (Z)-	$C_{23}H_{46}$	322	4.81	27519-02-4
58	21.40	83	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	348	3.70	7225-68-5
59	22.36	43	Heptacosane	$C_{27}H_{56}$	380	5.21	593-49-7
60	23.06	69	9-Tricosene, (Z)-	$C_{23}H_{46}$	322	5.58	27519-02-4
61	23.39	83	1-Heptacosanol	$C_{27}H_{56}O$	396	4.54	2004-39-9
62	24.27	43	Tetrapentacontane, 1,54-dibromo-	$C_{54}H_{108}Br_2$	914	7.52	N/A
63	24.92	43	Cyclopentane, (4-octyldodecyl)-	$C_{25}H_{50}$	350	5.87	5638-09-5
64	25.19	57	Ethanol, 2-(octadecyloxy)-	$C_{20}H_{42}O_2$	314	4.94	2136-72-3
65	25.56	69	17-Pentatriacontene	$C_{35}H_{70}$	490	10.5	6971-40-0

Gas Chromatography and Mass Spectrometer (GC/MS) analysis of PP waste plastic to fuel oil (**fig. 4 and table 2**) in accordance with the various retention times and trace masses different types of hydrocarbon compounds are appeared in the analysis result index. Many compounds are emerged on the analysis such as carbon range C_4 to C_{35} at temperature 340°C to 3650 °C carbon chains of hydrocarbon breaking down into different ranges among them few of compounds are discussed. Based on the retention time and trace mass following hydrocarbon compounds as follows such as at the initial phase of the analysis at retention time 1.60 and trace mass 41, compound is 1-Propene, 2-methyl- (C_8H_8), retention time 1.91 and trace mass 43, compound is Pentane (C_8H_{18}), retention time 2.31 and trace mass 43, compound is Pentane, 2-methyl- (C_4H_{14}), retention time 2.99 and trace mass 67,compound is 1,3-Pentadiene, 2-methyl-, (E)-, (C_6H_{10}), retention time 3.05 and trace mass 56,compound is 1-Pentene, 2,4-dimethyl-(C_7H_{14}), retention time 3.11 and trace mass 55,compound is 2-Pentene,3-ethyl-(C_7H_{14}), retention time 3.14 and trace mass 81,compound is 2,4-dimethyl,1,4-Pentadiene (C_7H_{12}), retention time 3.28 and trace mass 41,compound is Pentane-2-Bromo-2-mentyl-($C_6H_{13}Br$),retention time 3.40 and trace mass 43, compound is Hexane-3-methyl-(C_7H_{16}), retention time 3.52 and trace mass 43,compound is 2-Pentanone ($C_5H_{10}O$), retention time 3.56 and trace mass 56, compound is 1-Hexene, 2-methyl- (C_7H_{14}), retention time 4.74 and trace mass 43, compound is Heptane-4-methyl-(C_8H_{18}), retention time 5.91 and trace mass 69, compound is Cyclohexane,1,3,5-Trimethyl-,(1α,3α,5α), retention time 5.99 and trace mass 43, compound is 2,4-Dimethyl-1-heptene (C_9H_{18}), retention time 6.34 and trace mass 69, compound is Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5β)-(C_9H_{18}), retention time 6.88 and trace mass 43,compound is Dicyclopropyl carbinol ($C_7H_{12}O$), retention time 8.93 and trace mass 43,compound name is Decane, 4-methyl- ($C_7H_{12}O$), retention time 10.01 and trace mass 41,compound name is 3-Dodecene, (E)- ($C_{12}H_{24}$), retention time 10.08 and trace mass 41, compound is 1-Octene, 3,7-dimetnyl-($C_{10}H_{20}$), retention time 10.76 and trace mass 41, compound is Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-, (1R-cis)-($C_{11}H_{22}O$), retention time 10.87 and trace mass 41, compound is 2-Undecanethiol, 2-methyl- ($C_{12}H_{26}S$), retention time 11.14 and trace mass 69, compound is 2-Isopropenyl-5-methylhex-4-enal ($C_{10}H_{16}O$), retention time 11.18 and trace mass 41,compound is Pentatonic acid, 10-undecenyl ester ($C_{16}H_{32}O_2$), retention time 11.44 and trace mass 69, compound is 1-Isopropyl-1,4,5-trimethylcyclohexane ($C_{12}H_{24}$), retention time 12.09 and trace mass 69, compound is compound is 1b,5,5,6a-Tetramethyl-octahydro-1-oxa-cyclopropa[a]inden-6-one ($C_{13}H_{20}O_2$), retention time 12.40 and trace mass 43, compound is Decane, 2,3,5,8-tetramethyl- ($C_{14}H_{30}$), retention time 12.95 and trace mass 83, compound is E-2-Hexadecanol-1-ol ($C_{16}H_{32}O$), retention time 13.02 and trace mass 43, compound **is** 4-Hydroxy-4-methylhex-5-enoic acid, tert.-butyl ester ($C_{11}H_{20}O_3$), retention time 13.65 and trace mass 43, compound is Isotridecanol- ($C_{13}H_{28}O$),

retention time 14.38 and trace mass 55, compound is E-2-Octadecadecen-1-ol ($C_{18}H_{36}O$), retention time 15.84 and trace mass 43, compound is 1-Decanol, 2-hexyl- ($C_{16}H_{34}O$) , retention time 17.16 and trace mass 69, compound is 9-Eicosyne ($C_{20}H_{38}$), retention time 20.37 and trace mass 43, compound is Cyclopentane, (4-octyldodecyl)- ($C_{25}H_{50}$). Also at retention time 24..27 and trace mass 43, compound is Tetrapentacontane, 1,54-dibromo- ($C_{54}H_{108}Br_2$) and ultimately retention time 25.56 and trace mass 69, compound is 17-Pentatriacontene ($C_{35}H_{70}$) respectively.

Some ASTM test was preformed for fuel oil by 3rd party such as API Gravity at 60 ºF (ASTM D287), Density (ASTM D1298), Relative Density (Elevated temp) (ASTM D4052), Flash Point Test (ASTM D93_B), Pour Point Test (ASTM D97), Sediment Content (ASTM D473), Sulfur Content (ASTM D4294), Viscosity - Kinematic at 40 & 100 ºC (ASTM D445), Water Content (ASTM D95), Appearance or Haze (ASTM D4176), Cetane Index (Calculation Only) (ASTM D976), Cloud Point (ASTM D2500), Color (ASTM D1500), Copper Corrosion (ASTM D130), Distillation (ASTM D86), Oxidation Stability (ASTM D2274), pH Value (ASTM D1293), Btu value gal or lb (ASTM D240).

4. Conclusion

The thermal degradation of PP waste plastic to produced fuel oil was successfully characterized by using GC/MS, FT-IR and DSC equipments. The produced heavy fuel was found brownish color and acrid smell. The GC/MS analysis was found from heavy fuel has carbon chain range C_4 to C_{35} which is similar to fuel grade oil. Some of ASTM (American Standard and Testing Method) test was performed with produced fuel and determined less sulfur content and high BTU values in the fuel. The heavy fuel oil FT-IR analysis result showed dominant with pronounced functional groups which indicate the presence of alkanes and alkenes. However, in the case of waste PP to heavy fuel oil production cost lower when commercial plant will be started and this fuel could be use in to heavy equipment and feed stock refinery for further modification. The fuel oil grade PP 5th fractional fuel could be the alternative of renewable energy as well as the world can reduce the fuel oil dependency from natural resources and other fuel reach recourse countries where the fuel price is raised up very high in terms of unavoidable factors. By developing the pilot plant individual countries and community would be capable to earn foreign currency by exporting the fuel oil and the nations will turns into self reliant fuel oil reach countries and can back up fuel oil demand for its own domestic various purposes.

Acknowledgement

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

References

[1] Uemichi Y, Hattori M, Itoh T, Nakamura J, Sugioka M (1998) Deactivation behaviors of zeolite and silica–alumina catalysts in the degradation of polyethylene. Ind. Eng. Chem. Res. 37, 867– 872.

[2] Ding W, Liang L, Anderson L. L (1997) Thermal and catalytic degradation of high density polyethylene and commingled post-consumer plastic waste. Fuel Process. Technol. 51, 47–62.

[3] Zhibo Z, Nishio S, Morioka Y, Ueno A, Ohkita H, Tochihara Y (1996) Thermal and chemical recycle of waste polymers. Catal. Today. 29, 303– 308.

[4] Kargfz S, Karayildirim T, Ucar S, Yuksel M, Yanik J (2003) Liquefaction of municipal waste plastics in VGO over acidic and non-acidic catalysts. Fuel. 82 (4), 415– 423.

[5] Songip A.R, Masuda T, Kuwahara H, Hashimoto K (1994) Production of high quality gasoline by catalytic cracking over rare-earth metal exchanged Y-type zeolites of heavy oil from waste plastics. Energy & Fuels. 8, 136–140.

[6] Kastner H, Kaminsky W (1995) Recycle plastics into feedstocks, Hydrocarb. Process. 5, 109– 113.

[7] De la Puente G, Arandes J.M, Sedran U.A (1997) Recycled plastics in FCC feedstocks: specific contributions. Ind. Eng. Chem. Res. 36, 4530–4534.

[8] Serrano D.P, Aguado J, Escola J.M, Garagorri E (2003) Performance of a continuous screw kiln reactor for the thermal and catalytic conversion of polyethylene-lubricating oil base mixtures. Appl. Catal., B Environ. 44, 95– 105.

[9] Lovett S, Berruti F, Behie L.A (1997) Upgrading of plastic wastes and plastic/heavy oil mixtures to valuable light gas products. Ind. Eng. Chem. Res. 36 (11), 4436–4444.

[10] Arandes J.M, Erena J, Azkoiti M.J, Olazar M, Bilbao J (2003) Thermal recycling of polystyrene and polystyrene-butadiene dissolved in a light cycle oil. J. Anal. Appl. Pyrolysis. 70, 747– 760.

[11] Pinto F, Franco C, Andre R.N, Miranda M, Gulyurtlu I, Cabrita I (2002) Co-gasification study of biomass mixed with plastic wastes. Fuel. 81, 291– 297.

[12] Sakata Y, Azhar Uddin M, Muto A, Kanada Y, Koizumi K, Murata K (1997) Catalytic degradation of polyethylene into fuel oil over mesoporous silica (KFS-16) catalyst, J. Anal. Appl. Pyrolysis. 43, 15–25.